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PREFACE

The American Organizing Committee here acknowledge with due appreciation the financial assistance rendered by the business organizations and individuals who contributed unstintedly to the fund which financed the meetings and the transcontinental tour. The hearty and earnest coöperation of the Honorable Secretary of the United States Department of Agriculture and of the American Society of Agronomy contributed to the success of the Congress and is gratefully acknowledged. Likewise their thanks are due to the United States Chamber of Commerce for the splendid facilities provided for the meetings and the exhibits of the Congress, and to the Pan American Union and the National Gallery of Art for the use of their buildings for social functions.

The papers of the several commissions of the First International Congress of Soil Science, that have been submitted for publication, are printed in the original language of the author, with the exception of those submitted in Russian, and the order of arrangement is that adopted in the Abstracts of the Proceedings. Those papers that were presented at the various sessions but were not sent in for publication are given by title at the end of their respective Commission.

The thanks of the American Organizing Committee of the International Congress of Soil Science and of the editor are due to Dr. A. R. Merz and Mr. P. R. Dawson for editing all papers written in foreign languages and to Mr. E. F. Snyder for editing many of the papers dealing with the subject of hydrogen ion investigations. They are particularly indebted to Mr. Dawson for the preparation of manuscript from material appearing in long hand. They also wish to acknowledge their indebtedness to Dr. J. S. Joffe for translating all of the papers given in Russian and to Mr. S. H. McCrory for the revision and editing of many of the papers of Commission VI.

The abbreviations used throughout the Proceedings and the Papers are those adopted by the American Chemical Society. In so far as possible references are given in a list at the end of each paper and are referred to by numbers in parentheses in the text. The volume number is given first and then the first page reference of the periodical. Otherwise the reference is given as submitted by the author. The summaries of papers have been omitted, since they are to be found in the abstracts distributed to members during the meetings of the Congress at Washington.

R. B. DEEMER,
Editor

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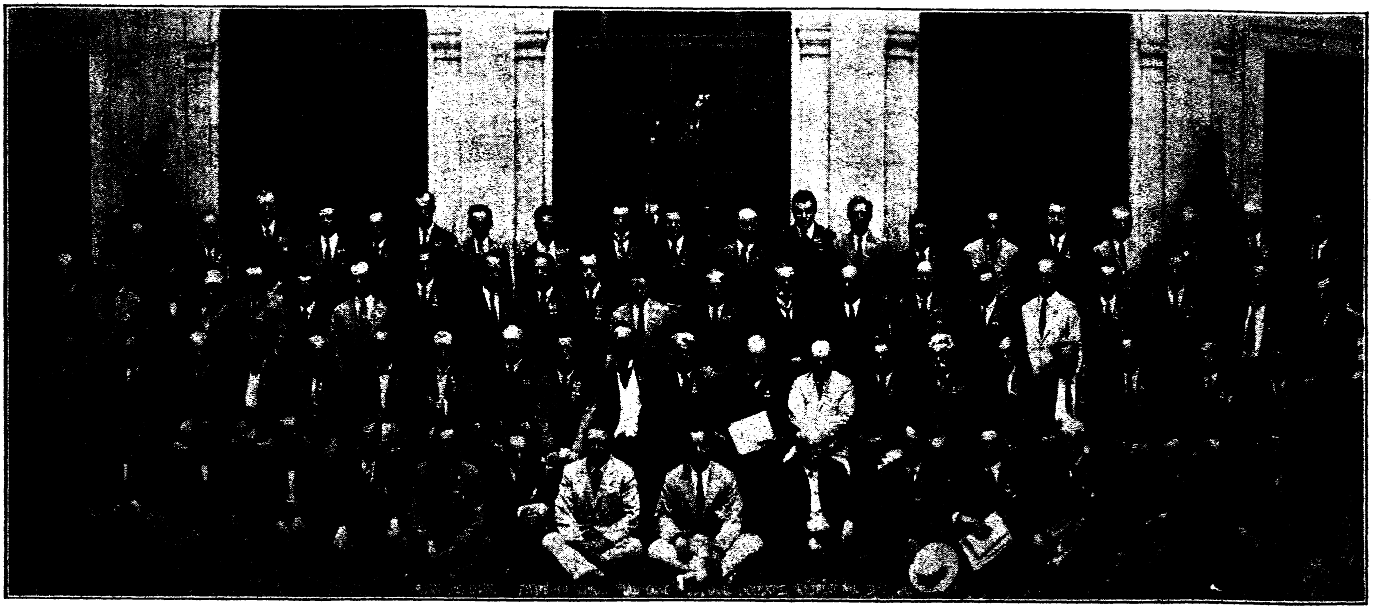
A. B. Fagundes, Brazil
M. F. Figares, Spain
A. J. Findlay, West Africa
N. Florov, Roumania
A. G. Floyd, Cuba
R. Ganssen, Germany
W. Gemmerling, U. S. S. R., Russia
F. P. Gerretsen, Holland
H. Gessner, Switzerland
O. T. Girsberger, Switzerland
K. D. Glinka, U. S. S. R. Russia
G. Goerz, Germany
M. Gorski, Poland
A. N. Goudilina, U. S. S. R. Russia
R. Griessbach, Germany
G. K. Groenewalt, Holland
T. D. Hall, South Africa
F. Hardy, British West Indies
E. Hauenschield, Washington, D. C.
A. Haushofer, Germany
J. Hendrick, Scotland
H. C. and Mrs. Henricksen, Porto Rico
T. C. Henricksen, Porto Rico
B. H. Hesselman, Sweden
H. Hesselman, Sweden
D. J. Hissink, Holland
V. Hohenstein, Germany
F. G. Holdaway, Australia
N. G. Horner, Sweden
T. Imaseki, Japan
A. Itano, Japan
H. Jenny, New Jersey
L. Tovborg and Mrs. Jensen, Denmark
J. Jurin, U. S. S. R. Russia
A. T. Kaigorodov, U. S. S. R. Russia
B. A. Keen, England
H. W. and Mrs. Kerr, Australia
N. R. Kleen, Sweden
C. H. Knowles, British West Africa
G. Krauss, Germany
S. Kravkov, U. S. S. R. Russia
Dr. L. and Mrs. Kreybig, Hungary
P. Krische, Germany
P. G. Krishna, India
A. F. and Mrs. Lebedeff, U. S. S. R. Russia
D. Lemmermann, Germany
R. E. MacEacher, Uruguay
V. C. Madsen, Denmark
W. S. Martin, British East Africa
G. Mata, Jr., El Salvador, C. A.
A. Matthei, Chile
E. Melin, Sweden
F. Mentchikowsky, Palestine
M. and Mrs. Mesa, Washington, D. C.
S. Miklaszewski, Poland
J. Mirtoff, New York
H. Misu, Japan
A. Mittasch, Germany
J. F. Montes, Spain
E. Naef, Switzerland
S. Neustruev, U. S. S. R. Russia
D. H. and Mrs. Niklas, Germany
V. and Mrs. Novák, Czechoslovakia
W. G. Ogg, Scotland
L. Orsenigo, Italy
H. and Mrs. Osvald, Sweden
H. J. and Mrs. Page, England
A. Penck, Germany
I. Peroni, Italy
B. Polynov, U. S. S. R. Russia
L. Prassalov, U. S. S. R. Russia
O. Ratib, Egypt
J. P. Rebello, Portugal
A. Reifenberg, Jerusalem
T. Rigg, New Zealand
G. W. Robinson, Great Britain
G. Rossati, Italy

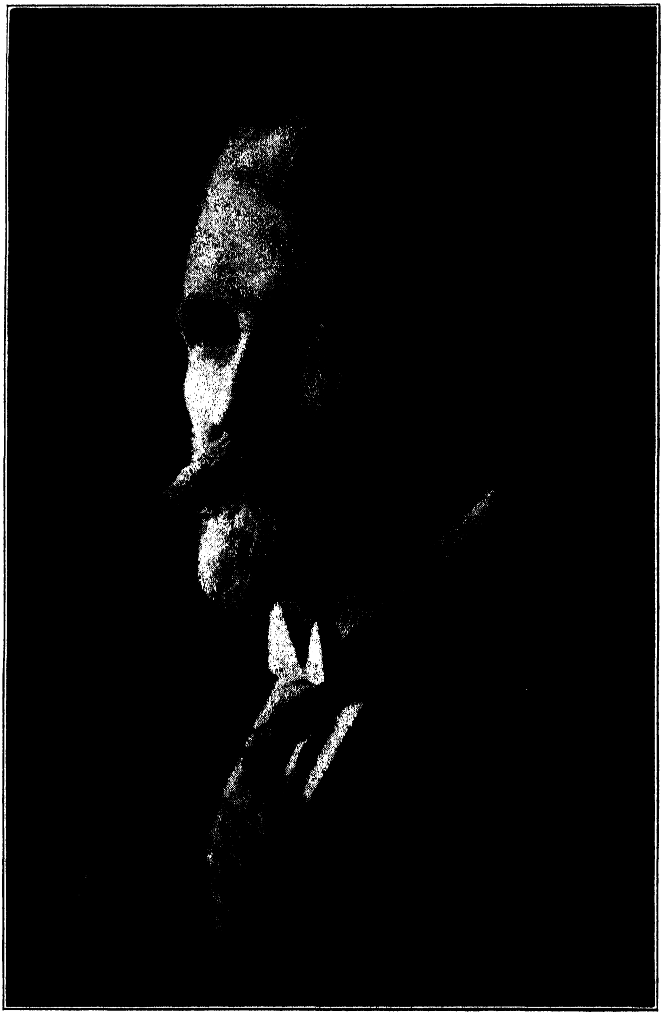
E. J. Russell, England
T. Saidel, Roumania
S. Sampaio, New York
E. R. Sawer, England
J. Schetelig, Norway
H. Schildknecht, Switzerland
A. Schmuck, U. S. S. R. Russia
F. Schucht, Germany
B. Schuster, Germany
E. Schuster, Germany
C. T. Sedlmayr, Vienna
K. Shiboya, Japan
W. Shimmon, England
A. Shoorigin, U. S. S. R. Russia
A. A. J. de 'Sigmond, Hungary
L. Smolik, Washington, D. C.
A. Sokolovski, U. S. S. R. Russia
H. Stremme, Germany
N. Takahashi, Japan
F. Tasch, Germany
Count C. Teleki, Hungary
T. Terho, Finland
F. Terlikowski, Poland
P. Toznay, Hungary
P. Treitz, Hungary
M. Trénel, Germany
N. M. Tulaikov, U. S. S. R. Russia
P. Turin, U. S. S. R. Russia
E. E. Uspensky, U. S. S. R. Russia
D. Vilensky, U. S. S. R. Russia
F. Weis, Denmark
S. Weis, Hungary
C. L. and Mrs. Whittles, British Guiana
G. Wiegner, Switzerland
M. Winnik, Palestine
W. Wolff, Germany
A. Yarilov, U. S. S. R. Russia
S. Zakkarov, U. S. S. R. Russia
J. C. Zavala, Nicaragua
Mme. Y. Ziemiecka, Poland
M. Zulficar, Egypt



Foreign Delegates, First International Congress of Soil Science, Washington, D. C., 1927

FOREIGN DELEGATES

1. Augusto Bonazzi, Italy
2. H. J. Page, England
3. J. Mirtoff, Russia
4. G. W. Robinson, England
5. B. A. Keen, England
6. A. A. J. de 'Sigmond, Hungary
7. A. L. de Kreybig, Hungary
8. Charles Teleki, Hungary
9. Peter Treitz, Hungary
10. A. Shoorigin, Russia
11. H. M. Nagant, Canada
12. Frank T. Shutt, Canada
13. Thos. Rigg, New Zealand
14. Charles A. Fontaine, Canada
15. H. Hesselman, Sweden
16. N. H. Niklas, Germany
17. B. Schuster, Germany
18. Paul Krische, Germany
19. R. Albert, Germany
20. E. Abad, Spain
21. V. C. Madsen, Denmark
22. S. Miklashevski, Poland
23. E. J. Russell, England
24. D. J. Hissink, Holland
25. K. D. Glinka, Russia
26. A. Penck, Germany
27. N. Stremme, Germany
28. B. Polynov, Russia
29. A. Jarilov, Russia
30. L. T. Prasslov, Russia
31. S. P. Kravlov, Russia
32. S. A. Sacharov, Russia
33. Mahmoud Abaza, Egypt
34. T. Imaseki, Japan
35. Elias Melin, Sweden
36. Hugo Oswald, Sweden
37. P. G. Krishna, India
38. Jadwiga Ziemiecka, Poland
39. M. S. Gorski, Poland
40. F. Terlikowski, Poland
41. R. MacEacher, Uruguay
42. A. Haushofer, Germany
43. C. Nikiforoff, U. S. A.
44. Victor Hohenstein, Germany
45. P. P. Jurin, Russia
46. N. M. Tulaikov, Russia
47. W. S. Martin, Uganda
48. T. Saidel, Roumania
49. M. Draces, Roumania
50. N. Florov, Roumania
51. J. G. Bijl, Holland
52. A. Sokolovski, Russia
53. A. A. Schmuck, Russia
54. W. W. Gemmerling, Russia
55. G. Wiegner, Switzerland
56. L. F. Smolik, Czechoslovakia
57. Meir Winnik, Palestine
58. A. J. Findlay, Nigeria
59. C. H. Knowles, Gold Coast
60. F. Hardy, Trinidad
61. C. L. Whittles, British Guiana
62. Adolph Reifenberg, Palestine
63. Hans Jenny, Switzerland
64. A. B. Fagundes, Brazil
65. A. B. Catley, Australia
66. H. W. Kerr, Australia
67. J. W. Turin, Russia
68. E. E. Uspenski, Russia
69. E. M. Crowther, England
70. K. Shibuya, Japan
71. Lopez Dominguez, Porto Rico
72. V. Novák, Czechoslovakia
73. F. Menchikowski, Palestine
74. C. T. Girsberger, Switzerland
75. F. Schucht, Germany
76. H. Gessner, Switzerland



PROF. DR. K. D. GLINKA, LENINGRAD, 1867–1927

PROFESSOR DR. KONSTANTIN D. GLINKA

Announcement of the death of Prof. Dr. K. D. Glinka, which occurred on November 2, 1927, was made officially by Prof. Dr. A. Yarilov in behalf of the Bureau of Soil Scientists of the U. S. S. R. and the U. S. S. R. Section of the International Society of Soil Science in their Bulletin. Dr. Glinka was President of the International Society of Soil Science, and Honorary Chairman of the Bureau of Soil Scientists. His death came after an illness of some three months' duration and followed closely upon his return to Europe after the transcontinental tour of America. Smolensk was the home of his birth, which occurred in August of 1867, thus he was only entering his sixty-first year when he passed away.

St. Petersburg University bestowed upon him his first academic degree in the year of 1889. His professor, Dr. W. W. Dokuchaiev, known as the creator of Russian Soil Science, who was then Professor of Mineralogy, induced him to take the step that determined Dr. Glinka's scientific career. He retained him as his assistant, appointing him to the Chair of Mineralogy. His duties here trained him for the professorship. His early learning was extended under the direction of the master as the latter imparted to his worthy student the details and fundamentals of his soil survey methods. In this pleasant work and formative studies he was joined by another of Dokuchaiev's gifted students, N. M. Sibirtsev. These two were invited by Dr. Dokuchaiev to join him in the work of the New-Alexandria Agricultural Institute. Dr. Sibirtsev filled the first Chair of Soil Study, in Russia, while Dr. Glinka served first, as assistant, and then as instructor of Mineralogy and Geology. The field of their activities was with the governments of Poltava and Pskov, Voronezh and Smolensk. In conjunction with his professor he conducted soil studies for them and, later, he was a coworker with Dr. Sibirtsev for them. Upon the death of the latter, in 1900, he succeeded him as Professor of Soil Science, in Poland.

The sending of Dr. Treitz and Dr. Timko, by the Hungarian Geological Committee, to New-Alexandria brought Dr. Glinka his first contact with Soil Scientists of western Europe. Since 1909 Dr. Glinka took part in the first and subsequent International Agro-geological Conferences and upon the foundation of the International Society of Soil Science he was elected an honorary member. The Sixth U. S. S. R. Conference of Soil Science named him candidate for president of the International Society and president of the Second International Congress of Soil Science, to be held in Russia in 1930, which culminated in the bestowal of this honor upon

him by the Congress in Washington, June, 1927, when he was elected President.

With Dr. Glinka's acceptance of the appointment to the professorship of Soil Science in the Agricultural Institute of New-Alexandria, Pulawa, Poland, he entered upon a new epoch of his career and his most interesting work resulted from this connection. Dr. B. Polynov, in the Proceedings of the International Society of Soil Science, Volume 3, writes of this work as follows: "These were principally connected with the Geography of Soils and gave a vast development to the well known principle of regularity pointed out by Dokuchaiev in the relation between climate and the processes of soil formation. During his many travels through Russia and western Europe (Hungary, Germany, France and Spain) undertaken always with the aim of research work in Soil Science, his efforts were unwearyingly directed towards the establishment of the limits of this or the other soil-climatic zone. Beginning with 1908 Glinka undertook the direction of many expeditions organized with the purpose of soil survey in the Asiatic part of Russia. The results of these investigations, together with an extensive physico-geographical literature formed the formations to the composition of the first soil map of all the territory of Russia although a soil map of the world had been previously compiled. While systematizing the material collected during the above expeditions K. D. Glinka observed a certain uniformity in the distribution of soils over Transbaikalia, the Yakutsk region and other areas which may account for certain interruptions and digressions of the soil zones. Thus the idea of Soil Provinces was put forward; this idea found its development later in the works of a member of the third generation of Dokuchaiev's pupils, the well known Russian soil scientist L. I. Prasolov."

"However, the works of K. D. Glinka are not concerned solely with soil-geography. The results of his research work in the field of the processes of weathering and of Paleopedology (fossil soils) occupy also an important place in the process of the development of our branch of science and establish the association of the latter with Mineralogy and Geology. It is likewise thanks to Glinka that the achievements of Russian scientists—Dokuchaiev and his numerous pupils—came to the knowledge of our central European and west European colleagues. In taking active part in the works of the Agro-geological Conferences in Budapest, Stockholm, Rome and Prague, as well as in creating during his travels many a friendship among the European scientists, Glinka tried always to extend the knowledge of Russian researches and publications. As a matter of fact the attention with which the Russian works in Soil Science were invariably encountered in Europe, must be partly ascribed to the activity of the much esteemed, late Prof. Dr. Ramann, who has awakened a great interest towards Russian researches. But Dr. Glinka alone was able to claim and extend this interest, and he knew well whom he could resort to in this

matter for support, as, for instance Dr. P. Treitz, Prof. Dr. H. Stremme, Dr. C. F. Marbut, Dr. G. Wiegner, Prof. Dr. F. Schucht, Dr. Benj. Frosterus, Prof. Dr. A. von Sigmond, Dr. Slav. Miklaszewski and others; these scientists were mentioned by him most willingly and invariably with the heartiest gratitude."

"Six months have not elapsed since we have seen Dr. Glinka full of life, strength and energy, taking part, together with many of his above mentioned friends, in our trip through America and in the numerous 'profile-examination' which accompanied it, teaching us or entering in animated discussions."

"These impressions, deeply engraved in our minds and the warm remembrances connected with this personality will become still more striking through his unexpected death and the bitterness of the irremediable and heavy loss."

The recently founded Chair of Soil Science of the U. S. S. R. Academy of Sciences was bestowed upon Dr. Glinka in April of 1927. While the U. S. S. R. Soil Scientists particularly feel the loss of their distinguished member, the whole group of the International Soil Scientists mourn his untimely death most keenly.

Milton Whitney, 1860–1927

MILTON WHITNEY

Prof. Milton Whitney who died at his home in Takoma Park, Md., early on the morning of November 11, 1927, was a native son of the State of Maryland. His death was due to angina pectoris, but in spite of his long illness and suffering he was active in research to the time of his death, symbolical of his untiring service to his profession. He was undoubtedly one of the outstanding world authorities in soil science and early in his career became Chief of the Bureau of Soils of the United States Department of Agriculture. He suffered a severe attack of the disease with which he was afflicted in March, 1925, from which he never entirely recovered and because of this illness he was unable to attend the meetings of the Congress. The international respect with which his attainments were regarded was probably never more adequately recognized than when, at the opening session, the Congress paused to adopt a resolution of regret that he was unable to attend because of this illness, and to acknowledge his place as a soil scientist.

He was a native of Baltimore, Md., where he was born, August 2, 1860. His early education was, therefore, received in the Baltimore schools. Johns Hopkins University was a natural selection for special preparation for his professional career and three years' association with the famous chemist, Dr. Ira Remsen, inspired him to give his attention to soils and their relation to plant growth. His first assignment in this field of work came at the conclusion of his studies at Johns Hopkins, in 1883, when he became assistant chemist of the Connecticut Agricultural Experiment Station. Some three years later his activities were transferred to the North Carolina Experiment Station when he became superintendent of the experiment farm. Through this connection he acquired the practical experience in the handling of soils which later proved of great value to him in his scientific studies of them. The report of his work at this station directed attention to the profound influence that physical properties of soils have upon crop production.

South Carolina contributed her share in the shaping of the career of this emminent scientist when she extended him the Chair of Professor of Agriculture in the University, in 1888, and also made him vice director of the experiment station. We next find him connected with the Maryland Experiment Station and it was while there, that the Weather Bureau of the Department of Agriculture placed funds at his disposal to enable him to complete a full report on soil investigations, which appeared as Bulletin No. 4 of that Bureau.

"The Department of Agriculture was so impressed with the necessity for study of the great problems of the soil as set forth in Professor Whitney's bulletin that it established a division of soils in 1894, and he was selected as its head. The work of the early division grew until Congress established it as a bureau in 1901, with Professor Whitney as chief. Although he retired as active chief of the bureau last June, he continued his research work in the bureau to the end. He was 67 years of age. He had been in the Department of Agriculture for 33 years. Under his direction the work of the bureau expanded greatly and covered many lines of investigation. He established the Soil Survey, an organization having for its objective the mapping of the soil types of the entire United States. This undertaking has proved its worth, and to-day more than one-third of the arable lands of the United States have been painstakingly mapped to show the extent and location of the various types of soil."

"Early in its history the Bureau of Soils undertook a study of the alkali problem of the western lands and a method was devised for the reclamation and handling of alkali soils. Under Professor Whitney's direction the study of soils, with reference to their suitability for tobacco growing, was inaugurated, and it was he who was chiefly instrumental in the establishment of tobacco growing under shade in the Connecticut River Valley. He directed the Government's work on the fixation of atmospheric nitrogen; and in 1911, when there arose the threat of a German monopoly of the potash supply, he threw his organization into the field for the development of adequate domestic sources of potash and also other fertilizer materials. Under his direction a systematic study of the phosphate fields of the country was carried on."

"For many years Professor Whitney recognized the necessity for the conversion of the fertilizer industry from the status of what he was wont to call a 'scavenger industry' into the position of a true chemical industry. To this end he pressed a vigorous study of concentrated fertilizers, both as to methods of manufacture and of application, and highly gratifying results have been obtained."

"To him fell the burden of administering the fertilizer control under the food control act in the years 1919, 1920, and 1921. He approached this task with characteristic vigor, and through the trying post-war days worked early and late for fair treatment for both the farmer and the industry."

"Professor Whitney was a man of strong convictions and one whose vision was never obscured by petty disturbances of the immediate present. It was his constant urge upon those younger men whose privilege it was to work close to him that they should have the courage of their convictions, not always to be content to follow but to lead, to realize that universal commendation is rare and that criticism should not be feared for any work well done. Students of soil science generally have come to

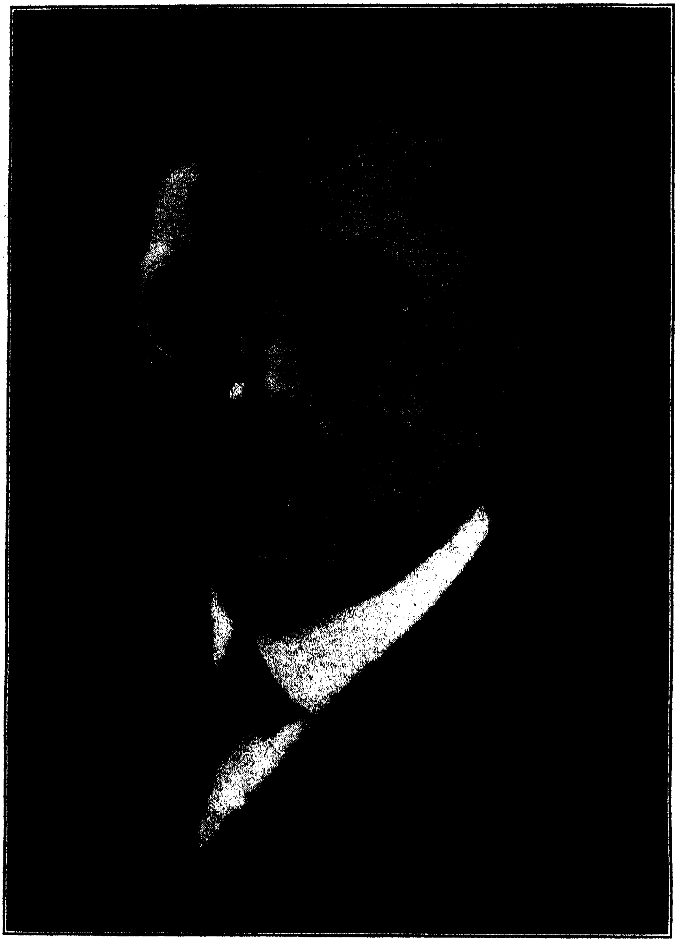
recognize that his courageous presentation of his views and conceptions has been probably the greatest influence in the furtherance of the scientific study of soils."

"Professor Whitney's most recent book, 'Soils and Civilization,' has attained a wide circulation, and has been very favorably commented upon by many of the prominent soil scientists of the world. He is also the author of numerous scientific articles and papers published both within and outside the department."

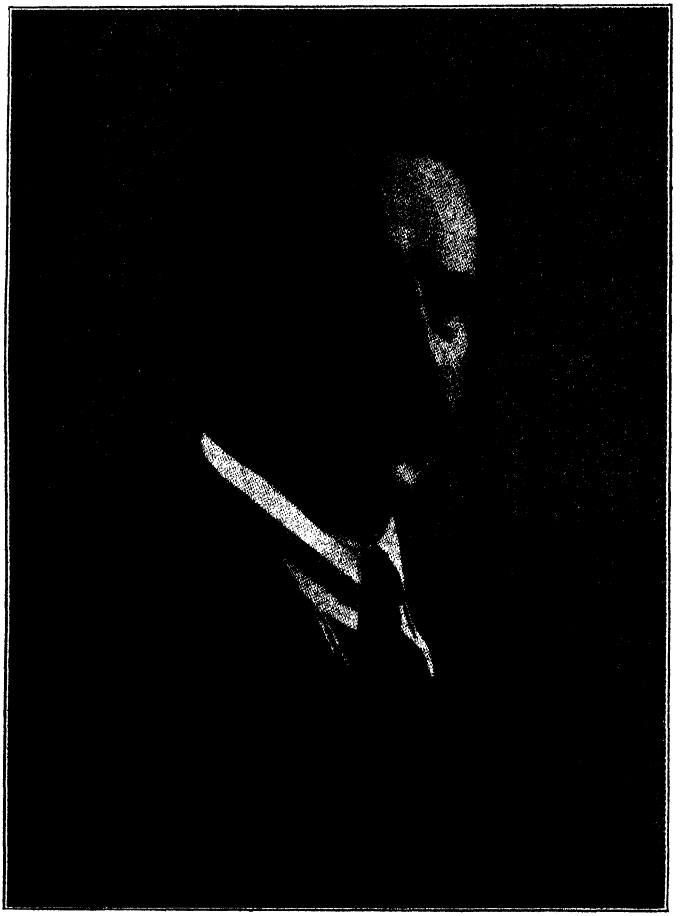
"He was a member of the Cosmos Club, the National Geological Society, the American Chemical Society, the Association of Agricultural Chemists, and the American Soil Survey Association."

"The funeral services were at Trinity Episcopal Church in Takoma Park on Monday. Burial was in Rock Creek Cemetery, Washington, D. C."

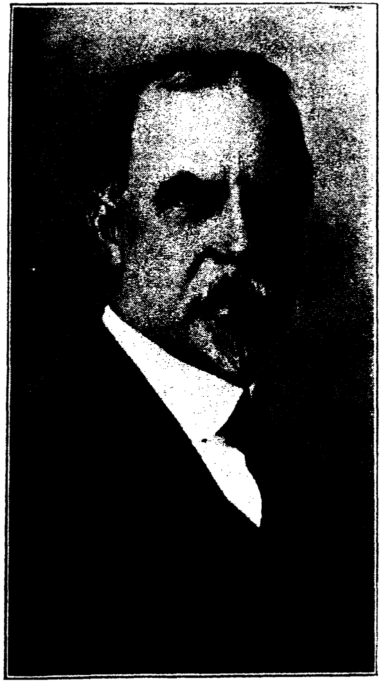
Ladies Attending First International Congress of Soil Science, Washington, D. C., 1927



DR. J. G. LIPMAN
Retiring President



Dr. K. K. Gedroiz
President Elect



Dr. Oswald Schreiner
Chairman Executive Committee

Courtesy, Fertilizer Review
Dr. A. G. McCall
Executive Secretary

Dr. D. J. Hissink
General Secretary

THE FIRST INTERNATIONAL CONGRESS OF SOIL SCIENCE

HISTORICAL

The first international gathering of soil scientists was held at Budapest, Hungary, in 1909 under the patronage of the Royal Minister of Agriculture. To Dr. Treitz belongs the honor of suggesting this meeting, a suitable recognition being accorded him later by the Society through the bestowing upon him of honorary membership. Invitations to this first meeting were issued by Professor L. von Lóczy. At this time an International Agro-geological Commission was founded with Béla von Inkey as Secretary.

A year later a second conference was held at Stockholm, Sweden, meeting simultaneously with the Agro-geological Conference; Dr. Anderson presided as President of the former and Dr. Hesselman held the post of Secretary of the latter. At this time, the Organizing Committee came into being which was to be elected for each future congress. St. Petersburg was chosen for the 1914 Congress, and the Russian Committee was under the leadership of Dr. Karpinsky. Prof. Wahnschaffe was entrusted with the commission of launching the publication of a journal, and for the first time separate commissions were organized to deal with special fields of investigation of interest to the members of the Society: (A) Classification of the soil particles obtained by means of Mechanical Analysis, President Dr. de'Sigmond, Hungary; (B) Preparation of soil extracts for Chemical Analysis, President, Dr. de'Sigmond, Hungary; (C) Nomenclature of moraine soil types in West Europe, President, Dr. Frosterus, Finland.

The period of the intervening four years was characterized by active interest in the Society. The commission in charge of Dr. Atterberg met in 1913 at the Geologischen Landensanstelt in Berlin and at this time became known as "Commission for Physical and Mechanical Properties of Soil," and just a year later Dr. de'Sigmond called his commission together at Münich. The title "Commission for Chemical Analysis of Soils" was adopted. The Third Commission did not meet in formal session this year, and circumstances made it impossible for Dr. Karpinsky to carry into effect the original idea of meeting in Russia.

After an interval of some years, the first steps were taken in the summer of 1921, by Dr. Hissink, Professor Schucht and Dr. Kopécky, towards resumption of scientific relations. Happily this resulted in the calling together of a third conference which met at Prague, Czecho-

slovakia, in 1922. It is worthy of notice that this Third International Conference was the *first* post-war international gathering of scientists. Growth of the Society may be seen in the reorganization of the commissions already formed, the organization of two new ones and two new subcommissions. Commission I retained its original title, but a new president was elected at this meeting, Dr. Novák; a subcommittee for the Application of Soil Science to Agricultural Technology was introduced under Dr. Girsberger. Commission II, became known as "Soil Chemistry," with its former President presiding. Commission III, with two Presidents, Dr. Lipman and Professor Stocklasa, with the title "Soil Biology" was organized at this time. Commission IV, under two presidents, Professor Murgoci and Dr. Marbut, was given the title of "Cartography," and finally Commission V appeared under the leadership of Professor Frosterus and Dr. Glinka to which was given the title of "Nomenclature and Classification." A subcommission for arid soils was organized under Dr. Marbut.

Two years later a fourth conference was held at Rome, under the patronage of the King of Italy and under the auspices of the International Institute of Agriculture. A committee was formed, after Dr. Borgesani's invitation was accepted, with Professor Kopécky as President, and Dr. Hissink as Secretary, to make the necessary arrangements. The Fourth International Conference met at the International Institute of Agriculture, Rome, in May 1924, the arrangements being in the hands of an Italian Organizing Committee of which Professor d'Ossat was President and Professor Perotti, the Secretary. The International Society of Soil Science was formally constituted on the last day of the Conference. Its objects were to be the forwarding of soil science by the holding of congresses and meetings, the formation of sections and commissions, the publication of a journal and the formation of a central library at the International Institute.

At this meeting, the following officers were elected: President, Dr. J. G. Lipman; Acting President and General Secretary, Dr. D. J. Hissink; Vice Presidents, Professor Angelis d'Ossat and Dr. B. Frosterus; Representative of the International Institute, Ing. Fr. Sevilla; Editor, Professor Schucht; Librarian, Dr. Borghesani.

The following commissions were organized:

I. Soil Physics (Professor Novák)
II. Soil Chemistry (Professor de'Sigmond)
III. Soil Bacteriology (Professor Stoklasa)
IV. Soil Fertility (Professor Mitscherlich)
V. Nomenclature, Classification and Mapping of Soils (Dr. Marbut)
  (a) Subcommission for the General Mapping of the Soils of Europe (Prof. Murgoci)
  (b) Subcommission for Alkali Soils (Professor de'Sigmond)

VI. Application of Soil Science to Agricultural Technology (Dr. Girsberger)

With the scope of the organization so materially enlarged, it was decided to hold a world-wide conference and America was selected as the first meeting place. Dr. Lipman was authorized to form an American Organizing Committee to prepare for the First International Congress of Soil Science. Soon after the Rome conference preparations were made to organize the Congress under the auspices of the American Society of Agronomy working through an American Organizing Committee. The cooperation of the United States Government was secured through the United States Department of Agriculture, and by an Act of Congress the President of the United States was authorized to extend invitations to the nations of the world to send official delegates. The American Organizing Committee functioned through an incorporated organization. The Corporation was formed February 12, 1926, to conduct the affairs of the Congress.

The First International Congress of Soil Science, therefore, is the result of the cooperative efforts of the International Society of Soil Science, the American Society of Agronomy and the United States Government.

GENERAL PROGRAM

Condensed Daily Schedule

FIRST DAY—MONDAY, JUNE 13

10:00 A.M.	Registration, United States Chamber of Commerce Building.
1:45 P.M.	Delegates will assemble for the opening exercises.
2:00 P.M.	Address by the Honorable Calvin Coolidge, President of the United States.
	Response by Dr. J. G. Lipman, President of the International Society of Soil Science.
	Greetings from a delegate from each continent.
	Roll call of Scientific Societies.
	Roll call of delegates.
	Appointment of committees.
8:00 P.M.	Informal reception at the Willard Hotel for delegates, members and guests.

SECOND DAY—TUESDAY, JUNE 14

8:00 A.M.	Exhibits open for inspection.
9:30 A.M.	General session—
	(1) Reports by the Presidents of the several commissions (20 minutes each).
	(2) Presidential address, Dr. J. G. Lipman, New Brunswick, N. J.
	(3) Address—Fertilizers and Soil Science, Mr. C. H. McDowell, Chicago, Illinois.
2:00 P.M.	Meetings of the several commissions.
8:30 P.M.	Formal reception at the Pan American Union by the Honorable W. M. Jardine, Secretary of Agriculture (by invitation).

THIRD DAY—WEDNESDAY, JUNE 15

8:00 A.M.	Exhibits open for inspection.
9:30 A.M.	General session—Addresses:
	(1) The Bureau of Soils, Its Origin and Objects, Dr. A. F. Woods, Director of Research.
	(2) The Present Status of Soil Biology, Sir E. J. Russell, Director Rothamsted Experimental Station.

(3) Determination of Soil Acidity, Dr. O. Lemmermann, Berlin, Germany.
(4) The Rôle of Geology in Soil Science, Dr. G. De Angelis d'Ossat, Italy.
(5) The Present Status of Soil Investigations in Japan, Dr. A. Itano, Ohara Agricultural Institute, Japan.

2: 00 P.M. Meeting of the several commissions.
8: 00 P.M. Formal dinner at the Willard Hotel.

FOURTH DAY—THURSDAY, JUNE 16

7: 30 A.M. Assemble at the Willard Hotel for a motor bus excursion into Western Maryland.
12: 00 A.M. Luncheon at Hagerstown.
7: 00 P.M. Dinner en route.
11: 00 P.M. Arrive at Washington.

FIFTH DAY—FRIDAY, JUNE 17

8: 00 A.M. Exhibits open for inspection.
9: 30 A.M. General session—
(1) The Chemical Characteristics of Soil Leachings, Dr. A. A. J. de'Sigmond, Budapest, Hungary.
(2) Trend of Land Utilization in the United States, Dr. O. E. Baker, United States Department of Agriculture.
(3) The Productive Capacity of the Globe, Dr. A. Penck, University of Berlin, Germany.
(4) A Brief History of Russian Soil Science, Dr. K. D. Glinka, Leningrad, Russia.

2: 00 P.M. Session devoted to a discussion of the genesis, morphology, classification and mapping of soils, to be led by the Russian delegation.
8: 00 P.M. Session devoted to a discussion of chemical and physical investigations, humus, soil dynamics and agronomic investigations to be led by the Russian delegation.

SIXTH DAY—SATURDAY, JUNE 18

8: 00 A.M. Exhibits open for inspection.
9: 30 A.M. Meetings of the several commissions.
2: 00 P.M. Meeting of the several commissions, or excursion to Mt. Vernon and Arlington Cemetery.
8: 00 P.M. Open for concert or other entertainment.

Seventh Day—Sunday, June 19

Open for rest or attendance at church or local excursions.

Eighth Day—Monday, June 20

8:00 A.M. Exhibits open for inspection.
9:30 A.M. Meetings of the several commissions.
2:00 P.M. Meetings of the several commissions.
8:00 P.M. Formal reception at the National Gallery of Art.

Ninth Day—Tuesday, June 21

7:00 A.M. Assemble at the Willard Hotel for motor bus trip to Baltimore. Luncheon at Baltimore.
5:00 P.M. Leave Baltimore.
7:30 P.M. Dinner at University of Maryland.
10:00 P.M. Arrive at Washington.

Tenth Day—Wednesday, June 22

8:00 A.M. Exhibits open for inspection.
9:30 A.M. Separate meeting of the several commissions.
2:00 P.M. General session for committee reports and election of officers.
10:00 P.M. Embark on excursion train for transcontinental trip.

PART I

PROCEEDINGS

PROCEEDINGS OF THE FIRST INTERNATIONAL CONGRESS OF SOIL SCIENCE

GENERAL SESSIONS

FIRST DAY—MONDAY, JUNE 13, 1927

10:00 A.M.—The entire morning was devoted to registration of delegates, members, and visitors at the United States Chamber of Commerce Building, Washington, D. C. Many of the delegates and members took advantage of this period to renew old friendships and to meet and make new acquaintances.

1:45 P.M.—The delegates assembled promptly for the opening exercises and were addressed by the Honorable Calvin Coolidge, who was introduced by Dr. Lipman.

Ladies and Gentlemen: We are signally honored by the presence among us of President Coolidge. He will now address us.

ADDRESS OF THE PRESIDENT OF THE UNITED STATES

HONORABLE CALVIN COOLIDGE

The fundamental importance of the soil as a great national and international asset is at once apparent when we reflect upon the extent to which all mankind is dependent upon the soil either directly or indirectly for food, clothing and shelter. Long after our mines have ceased to give up their treasures of iron, coal, and precious metals the soil must continue to produce the food necessary for feeding the ever increasing populations of the world.

It is highly proper therefore that representatives of the nations of the earth assemble in groups such as this for the purpose of discussing methods to be employed in the study of the problems of soil conservation and land utilization. The interchange of ideas and the personal contacts made possible by this international gathering cannot fail to be productive of a better understanding between the peoples of the earth and ultimately lead to a more universal desire for peace between all nations.

Being a young nation we have not, as yet, been forced to conserve our great natural resources as have some of the older nations where pressure of population on food supply has long since become acute, and has forced them to consider means for conserving the fertility of their soils and at the same time increasing the yield per acre. In the past, with our abundance of fertile acres we have been able to greatly increase our total production through increased acreage and the use of improved machinery.

With practically all of our fertile land now under cultivation, further increases in total production must come from increased acre yields instead of from increased acreage as in the past. The rapid and continued concentration of our people into large industrial centers now makes it necessary to greatly increase the effectiveness of those who remain on the land in order to produce a food supply sufficient to feed our city population.

Recognizing the fundamental importance of the agricultural pursuits to the welfare and happiness of all of our citizens the Federal Government has long since adopted the policy of federal aid and support for Agricultural Colleges and institutions for agricultural investigations and research.

The first step in this direction was the establishment of a federal Department of Agriculture at Washington, by the Act of May 15, 1862, but it was not until 1889 that the Department of Agriculture was made an Executive Department under the supervision and control of a Secretary of Agriculture appointed by the President, by and with the consent of the Senate of the United States; the Secretary being a member of the President's Cabinet with a rank coordinate with that of the heads of the other Executive Departments of the Government.

From the humble beginning of a little more than a half of a century ago, the work of the United States Department of Agriculture has steadily grown to very large proportions. Recognizing the importance of this basic industry and its relation to the welfare of the citizens of the entire country, Congress has increased the appropriations from time to time. The last annual report of the Secretary of Agriculture (1926), shows a personnel of 20,742 employees, with a total of $157,485,000 expended under the supervision of the Department. The direct expenditures made by the Federal Department amounted to $44,500,000 of which $10,300,000 was available for research.

On the second day of next month, (July), we will celebrate the sixty-fifth anniversary of the passage of an Act by the Congress of the United States whereby certain public lands were donated to the states for the establishment and the support of Agricultural Colleges. As a result of this Act and subsequent appropriations by the Federal Government, supplemented by State appropriations, we now have publicly supported Agricultural Colleges in every state and territory of this vast country. In many states the Agricultural College is a separate institution but in others the instruction in agriculture is given in a College of Agriculture organized within a great state university. Following the establishment of these institutions for instruction in Agriculture, it soon became apparent that the work of these Agricultural Colleges would need the support of fundamental research and investigation if real progress was to be made. In many of the colleges research departments were organized and experimental work inaugurated to supplement the teaching work and to supply

information to the farmers. The facilities at the command of these Agricultural Colleges were not sufficient however, to meet the demands made upon them and the need for additional support for research became more and more apparent as the number of students seeking agricultural instruction increased. Realization of this need having been brought to the attention of members of the Congress of the United States a bill was introduced and passed in 1887, just a quarter of a century after the bill establishing the Agricultural Colleges, providing federal aid and support for state Agricultural Experiment Stations. This bill known as the Hatch Act supplemented by the Adams Act of 1906 and by the Purnell Act of 1925, provides and insures to every State and territory a perpetual income for the support of agricultural investigations which, in many of the states is generously augmented by appropriations from the state treasuries. These state experiment stations together with the research departments of the Federal Department of Agriculture constitute the greatest organized body of research workers in agriculture in the world today.

While the Federal Act establishing the state experiment stations covered the entire agricultural field, it specifically provided that so far as practicable all such stations shall devote a portion of their work to the examination and classification of the soils of their respective states and territories with a view to securing more extended knowledge and better development of their agricultural capabilities. By the Federal Act of 1902, the soils work of the United States Department of Agriculture, which had previously operated as a Division, was recognized and organized into a separate Bureau of Soils. At the present a further reorganization is being effected by which the research work of the Bureau of Chemistry is being combined with that of the Bureau of Soils into one large unit to be known as the Bureau of Chemistry and Soils.

I have briefly indicated to you the organization of agricultural research in the United States, in order that I might bring to your attention the extent to which our Government is interested in the great work to which this Congress is dedicated. I trust that this great gathering of soil scientists from all parts of the world will be productive of great good and that you will return to your respective institutions and countries with your minds enriched with new ideas and that you will carry back with you a renewed enthusiasm for the great work to which you have dedicated your lives.

RESPONSE BY THE PRESIDENT OF THE CONGRESS

Dr. J. G. Lipman responded on behalf of the members to the words of greeting of President Coolidge as follows:

Mr. President: In behalf of the International Society of Soil Science, under whose auspices this Congress is being held; in behalf of the officers

of the Congress; and in behalf of the delegates from many lands, I wish to thank you for the honor you have done us. Your personal interest in our undertaking will lighten our task and will quicken our desire to learn the secrets of soil fertility. We are fully aware of the meaning of soil and land problems in the life of nations. It is our hope that the meetings of this Congress will point the way more clearly and more hopefully toward the effective use of the soil resources of the world, toward prosperity and contentment in all lands, toward friendship and good will among the nations and toward a more stable material foundation on which mankind may build its spiritual kingdom.

Greetings from each Country officially participating in the meetings of the Congress were delivered by their delegate and these were followed by responses to roll call of American and European Scientific Societies. Dr. Lipman then announced the appointment of several special committees provided for conducting the business of the Congress.

4: 00 P.M.—The ladies attending the meetings were entertained at an afternoon tea, with Mrs. Clyde Marquis, of the Hospitality Committee, presiding as hostess.

8: 00 P.M.—A delightful informal reception was held at the New Willard Hotel for delegates, members and guests.

SECOND DAY—TUESDAY, JUNE 14, 1927

8: 00 A.M.—Exhibits displaying (1) Representative soil types, (2) Methods and apparatus for chemical and physical analysis of soils, (3) Soil flora and fauna and apparatus and methods used in the biological and biochemical soil investigations, (4) Soil maps and plans of different regions of the world, and (5) A collection of the soil literature of the United States were opened to delegates, members and the public.

The ladies attending the Congress were entertained throughout the morning by a motorbus sight-seeing trip which included the principal points of interest in historic Washington. Mrs. Oswald Schreiner planned and carried out this delightful trip.

GENERAL SESSION—PRESIDENTIAL REPORTS

9: 30 A.M.—Dr. D. J. Hissink, Acting President of the International Society of Soil Science, reported the work of the Society that had been transacted since the Fourth Conference at Rome, 1924.

REPORT OF THE ACTING PRESIDENT

DR. D. J. HISSINK

Mr. President, Ladies and Gentlemen: According to paragraph 13a of the By-laws, it is the duty of the Acting President of the International

Society of Soil Science to submit a Report on the work of the Society since the preceding Congress, that is, in the present case, since the nineteenth of May, nineteen twenty-four, the day on which the International Society of Soil Science was founded. Now, three years later, the Society has 934 members, from 43 countries (see Supplement No. 1).

It is my agreeable duty to allude at this point to the valuable support and cooperation of the Committees of these Sections. The names of the Representatives of the various National Sections are to be found in Supplement No. 2. I hope that those countries in which no National Sections as yet exist will now proceed to the formation of such Sections.

I regret to have to add that there are very considerable difficulties connected with the collection of subscriptions. It has been found that the payment of subscriptions can most conveniently be made through the National Sections.

Notwithstanding all the efforts made by the National Sections and by myself, the following amounts are still unpaid:

1924	F. 5.00
1925	84.00
1926	271.50
1927	638.50

In consequence of the enormous growth of the Society, a huge increase has taken place in the correspondence. In the three years of the Society's existence some 2500 letters have been received and about 2300 have been sent out. More particularly during the last five months, owing to the preparations for the American Congress, have great demands been made upon the Secretariate at Groningen. From January 24, 1927, to May 11, 1927, no fewer than 693 letters were sent out in English, French, and German.

At the Foundation Meeting at Rome the foundation fee, which was at the same time to be regarded as the subscription for the year 1924, was fixed at a minimum of 2 Dollars or 5 Dutch Guilders. The Executive Committee fixed the annual subscriptions for 1925, 1926, and 1927 at 6.50 Dutch Guilders, with an entrance fee of 2.50 Dutch Guilders for new members.

Since 1925 the Review of the Society has appeared, under the name of "The Proceedings of the International Society of Soil Science," in five languages (English, French, German, Italian and Spanish). It is edited by Professor Dr. F. Schucht, of Berlin, while the printing and publication, in accordance with paragraph 14 of the By-laws, is undertaken by the International Institute of Agriculture in Rome.

It is obvious that technical and linguistic errors are unavoidable in the publication of a scientific article in five languages. Moreover, it is felt that inconvenience is caused by the fact that the "Proceedings of the

International Society of Soil Science," sometimes appear considerably later than the "International Review of the Science and Practice of Agriculture," of which the Proceedings is a part, so that I have received quite a number of complaints from members on this point. It should, however, be remembered that a vast amount of work is involved in the publication of a journal in so many languages, nor should it be forgotten that the International Institute of Agriculture at Rome has done all this work—the translation, the printing, and the distribution of our journal—on terms which are very advantageous to our Society. The Session of the General Committee of the Society, held at Groningen on April 7, 1926, fully recognized this, and instructed its President, Dr. Lipman, when visiting Rome, to convey the thanks of the Society to the President of the Institute.

To my great regret I must add that I was informed by the President of the Institute, at the end of December 1926, that the finances of the Institute no longer admitted of the publication of the journal on the same terms in the year 1927. Professor Schucht and myself have since then succeeded in coming to a fairly favorable arrangement with the Institute for the year 1927, that is, for the publication of Volume III; which, however, will make great, but fortunately not insuperable, demands on the funds of the Society. For this fresh proof of helpfulness and support the thanks of the Society are also due the Institute. This new arrangement, however, holds good only for the year 1927, so that the duty rests upon this Congress of making a new arrangement for 1928 and succeeding years.

On April 7, 1926, the General Committee met at Groningen, with Dr. Lipman in the chair. A report of this meeting is included in the Journal (Volume II, 1926, No. 2, pp. 191–196).

The following meetings were also held:

The First Commission at Rothamsted, Harpenden, from October 15 to 19, 1926;

The Second Commission at Groningen, from April 2 to 6, 1926;

The Third Commission in Berlin, in November, 1925, and also in Berlin, October 22, 1926;

The Fourth Commission at Dusseldorf, September 21, 1926;

The Fifth Commission at Sopron, Hungary, in August, 1926.

In addition to these meetings, most of the National Sections met regularly. I attended the meeting of the German Society of Soil Science at Dusseldorf in September, 1926, and the Congress of the Russian Pedologists in Leningrad in January, 1927.

In addition to the Proceedings of the Society, the members have hitherto received gratis the following publications:

(1) The Conclusions of the First Commission Meeting at Rothamsted, Harpenden, 1926;

(2) The Transactions of the Second Commission, Groningen, Volume A (1926), and Volume B (1927);
(3) A Soil Map of Europe, with explanatory notes.

At the International Conference du Blé, held at Rome in April, 1927, the Society was represented by the Vice President, Professor de Angelis d'Ossat, while Professor de Angelis d'Ossat and Professor Perotti represented the Society at the Thirteenth Agricultural Congress, at Rome, in May, 1927.

This short and somewhat dry summary will give you some idea of the great strides made by the Society during its short existence.

In contrast to all this cause for rejoicing there is, however, a good deal of sorrow. We have to mourn the loss of a number of members who were dear to us all. I would ask the Congress, in token of reverence for the departed, to stand while their names are read:

Prof. Dr. G. André	Paris
Prof. G. Mürgoci	Bucuresti
Prof. Dr. E. Ramann	München
Dr. Harold R. Christensen	Lyngby
Prof. Dr. K. Alb. Vesterberg	Stockholm
Prof. Dr. E. Müller	Copenhagen
Prof. Dr. Z. Starzyński	Pulawy
Prof. Dr. E. Krüger	Hannover
C. D. Jones	New Brunswick

It does not come within the scope of this short report to give a sketch of the services of these members. I must content myself with paying a reverent tribute to their memory, in the name of the International Society of Soil Science.

At the Foundation Meeting of the Society at Rome it was resolved to apply the name "Congress" in the future to the meetings of the International Society of Soil Science, and the meeting was unanimously in favor of adopting Dr. Lipman's proposal to hold the First International Congress of Soil Science in Washington in 1927. It may here be said, with some pride, that this Congress, thanks to the work done in and by the various Commissions, has been prepared for in an exemplary manner. The Presidents of the Commissions: Novák, de'Sigmond, Stoklasa, Mitscherlich, Marbut, Stremme, Girsberger, as well as the members of the Committees, deserve the thanks of the Society and of the Congress for the great amount of work done by them. In this connection we may not forget to mention the great work done by the American Organizing Committee and especially Drs. Lipman, Schreiner, Marbut, and McCall.

Our thanks are no less due to the Editor of our Journal, Professor Dr. F. Schucht, of Berlin.

This brings me to the end of my report. The past three years have

proved beyond a doubt that the International Society of Soil Science has a real raison d'être. The Society has indisputably furthered Soil Science, and I confidently rely on its fruitful activity in this direction in the future as in the past. And inasmuch as its activities are international and its membership roll includes colleagues from nearly every country in the world, all of whom have the same object in view, the International Society of Soil Science will doubtless bear its part in the furtherance of good relations between the nations and *eo ipso* of World-peace.

Report of the Acting President, D. J. Hissink

Supplement 1—Number and Distribution of Members

Germany	91	Italy	27
Argentina	1	Japan	16
Austria	5	Latvia	7
Belgium	3	Lithuania	1
Cuba	4	Norway	21
Denmark	17	Palestine	5
Dominican Republic	1	Holland	23
Egypt	3	Dutch Indies	30
Spain	9	Poland	30
Esthonia	1	Portugal	1
United States	247	Rumania	11
Finland	16	Serb-Croat-Slovene State	2
France	11	Russia	141
Irish Free State	1	Sweden	35
Great Britain	51	Switzerland	19
India	11	Surinam	1
West Indies	5	Czechoslovakia	35
Sudan	1	Turkey	1
Australia	2	Uruguay	2
Canada	8		——
New Zealand	1		934
South Africa	7	Resignations	22
Greece	6	Canceled (mistakes)	8
Hungary	24	Died	6

Report of the Acting President, D. J. Hissink

Supplement 2—Representatives of National Sections

Germany: Prof. Dr. F. Schucht, Güntzelstrasse 59, Berlin Wilmersdorf.

Austria: Prof. Dr. Graf zu Leiningen-Westerberg, Hochschulstrasse 17, Wien XVIII.

Denmark: Prof. Dr. F. Weis, Kgl. Veterinaer og Landbøhjskole, Rolighedsvej 26, Kobenhavn (V).

Spain: Sr. D. H. del Villár, Lista 62, 3° der, Madrid.

United States of America: Prof. Dr. J. G. Lipman, Experiment Station, New Brunswick, New Jersey, U. S. A., and

Cuba: Mr. H. S. Reed, Citrus Experiment Station, Riverside, California, U. S. A.

Finland: Dr. B. Aarnio, Staatliches Bodenuntersuchungsinstitut, Bulevardinkatu 29, Helsinki, Suomi.

Irish Free State, Great Britain and Dominions: Dr. B. A. Keen, Rothamsted, Harpenden, Herts.

Hungary: Prof. Dr. A. A. J. de'Sigmond, Chemische Landesanstalt, Keleti Károly u. 24. Budapest, II.

Italy:

Norway: Dr. J. Lindeman, Landwirtschaftliche Hochschule, Ås.

Dutch-Indies: Dr. C. J. Bernard, Algemeen Proefstation voor Thee, Buitenzorg, Java.

Poland: Dr. S. Miklaszewski, Rue Szopena 6, Warsaw.

Rumania: Prof. E. I. Protopopescu, Pake, Soseaua Kiselef 2, Bucuresti.

Russia: Prof. A. A. Jarilov, Wosdwijenka 5, Gosplan, Moscow.

Switzerland: Dr. J. Girsberger, Kultur-Oberingenieur, Kaspar Escherhaus, Zürcih, I.

Czechoslovakia: Eng. K. Spirhanzl, Agropedological Institute, Karlovo nám 3. Praha, II.

COMMISSION I

THE STUDY OF SOIL MECHANICS AND PHYSICS

Dr. V. Novák, Czechoslovakia, reported upon a preliminary meeting of Commission I, held in October, 1926, at the Rothamsted Experimental Station, England which resulted in the preparation of the following program for discussion by the First International Congress:

A. An international decision on the following questions:
   - (1) The preparation of soil samples for mechanical analysis.
   - (2) The division of soil into fractions in mechanical analysis.

B. The discussion of these questions:
   - (1) The standard apparatus for mechanical analysis.
   - (2) The physical properties of the soil:
     - (a) What is the best method for the determination of water holding capacity and air capacity of the soil, its plasticity, moisture equivalent, heat of wetting, and other physical properties?
     - (b) What relation do these properties bear to the behavior of the soil in the field?

COMMISSION II

THE STUDY OF SOIL CHEMISTRY

Dr. A. A. J. de'Sigmond, Hungary, gave the following general report of the work of Commission II completed since the last international conference at Rome:

GENERAL REPORT OF THE SECOND COMMISSION

DR. A. A. J. DE'SIGMOND

As chairman of the Second Commission on the Chemistry of Soils, I have the pleasure of giving a very short general review of the fundamental results, accomplished in the International coöperative work of our Commission since the last International Conference—the Fourth International Conference of Soil Science, held in Rome in 1924. I do not intend to dwell on the impetus given by the Conference at Rome, the further development of which we may see in the large increase of the reports given in the sectional program of our Commission to-day. I shall restrict my report to the positive facts and results, which were accomplished by the members of the Commissions in those special lines of work, that were selected as special aims of our Commission by resolutions and instructions given at the last Conference at Rome.

The first resolution of the Commission, accepted by the Conference of Rome, treated the question of the unification of methods as regards the preparation of the soil solution with concentrated hydrochloric acid. In Rome, we provisionally and in principle, accepted the method of van Bemmelen-Hissink, but as some details required further research I was instructed to conduct coöperative experimental work on four soil types with the different members of the Commission. This was done and in my special report, "Conclusions Concerning the Uniform Preparation of Soil Extracts with Hydrochloric Acid," I shall report on the successful results obtained by this coöperative experimental work.

Most successful results were attained by the preliminary meeting of the Second Commission held in Groningen, Holland, in 1926. The two volumes of these proceedings are the best proof of our intensive work, the general results of which enables us to come here to the Congress with propositions which have been elaborated and already discussed, which we may now treat in our sectional meeting here.

The question of soil acidity and soil absorption was one of the subjects of our last Conference at Rome, which aroused the greatest interest of the members, and as it was necessary to clear up some of the main points in this field of Soil Science, the Second Commission appointed Dr. H. Christensen and Dr. D. J. Hissink referees on soil acidity and absorption questions. This selection proved very satisfactory and successful. The

two referees associated with Prof. Dr. Comber, Leeds (England), and Prof. Dr. R. Ballenegger, Budapest, Hungary, and myself, as Chairman, succeeded in bringing the members of the Second Commission to a special meeting, which treated only the questions of soil acidity and absorption. The meeting was held in Groningen, at the beginning of April 1926, and thanks to the eminent leadership of our referees and especially to the efficient organization by Dr. D. J. Hissink, we had a very successful preliminary meeting. The propositions we will treat at Saturday morning's combined session of Commissions II and IV, might cover very fundamental resolutions, as regards the different types of soil acidity and the different methods of their determination. As soil absorption phenomena are closely related to soil acidity or in a broader sense, soil reaction, the meeting of Groningen has also contributed a good deal to that line of work, as we shall see in our sectional meeting of Monday morning.

Both questions are closely related to lime-requirement of soil, and we have devised several methods for the determination of the lime-requirement (Kalkzustand) of soils.

The fact of most interest was that on our excursion, which was arranged by our Holland colleagues, we had an opportunity to see in practice the result of the application of this scientific work.

I cannot fail to call attention to the fact, that through the good efforts of Dr. D. J. Hissink, the editions of Volumes A and B of this meeting was issued in a way so that the publication of these two volumes did not draw upon the funds of the International Society of Soil Science. As Dr. H. Christensen died since the meeting at Groningen I felt called, as chairman of the Second Commission, to appoint two co-referees to assist Dr. D. J. Hissink, who will submit their combined reports to the sectional meeting on Saturday morning.

I may state here, as Chairman of the Second Commission, that this appointment of special referees of some special question of the Commission proved very successful, which we might do well to follow with other questions in the future. We see also, that by carrying on the special problems in special meetings and after thorough discussion presenting the results in the form of resolutions or proposals seems to be the most successful way to prepare the special problems and subjects for the Congress and to obtain a general understanding and agreement.

The meeting held in Groningen again proved that the best way of preparing a scientific and successful discussion is by the advanced distribution of the papers which are to be treated, so that all of the members will have time enough to read and consider the subjects treated. Besides this, through the general reports of the referees we are able to start right in with the discussions.

Thus I come to the end of my short general report of the work of the Second Commission since our last International Conference and I hope

the results of our present meeting will be at least as fruitful as was the special meeting of the Second Commission in Groningen.

COMMISSION III

SOIL BIOLOGY AND BIOCHEMISTRY

Dr. S. A. Waksman, United States, presented a general report of the work and transactions of Commission III undertaken since the Rome conference, in the absence of Dr. J. Stoklasa, Czechoslovakia:

GENERAL REPORT OF THE THIRD COMMISSION

DR. S. A. WAKSMAN

Unfortunately the president of this commission, Prof. Dr. Julius Stoklasa of Prague, Czechoslovakia, could not attend this congress himself and he asked me to submit the report of this commission.

The officers of this commission elected in Rome were as follows:

President: Prof. Dr. Julius Stoklasa, Prague, Czechoslovakia.

Vice Presidents: Dr. S. A. Waksman, New Brunswick, N. J., U. S A.; Prof. Dr. G. Rossi, Portici, Italy; Prof. Dr. H. Niklas, Weinhenstephan, Germany; Prof. Dr. H. Christensen, Denmark.

Secretaries: Dr. Conn, New York; Dr. Cutler, London; Dr. Ing. Doerell, Prague; Dr. Fred, Wisconsin; Dr. Nemec, Prague.

We are very sorry to announce the death of one of the Vice Presidents of the commission, namely, Prof. Dr. Christensen of Denmark.

A preliminary meeting of this commission for the Washington Congress was held at the Agricultural Institute in Berlin on October 22, 1926. Following the Welcome of the president, ten reports were submitted, as follows: Prof. Dr. Lemmermann (Berlin), Prof. Dr. G. Rossi and Prof. Dr. S. Ricardo (Portici), Prof. Dr. A. Rippel (Göttingen), Prof. Dr. H. Niklas (Weinhenstephan), Prof. Dr. H. Wiessmann (Rostock), Prof. Dr. K. Asō (Tokio), Prof. Dr. V. Aaltonen (Finnland), Prof. Dr. J. Zolcinski (Dublany), Prof. Dr. Julius Stoklasa (Prague), Doz. Dr. G. E. Doerell (Prague). Resolutions were formulated in regard to the organization of the congress in Washington.

The program of this commission as organized at the present time will consist of seven sessions. All the papers submitted to this commission were grouped in a logical manner into these seven sessions, so that each session will cover a definite phase of the subject of soil microbiology such as the methods of microbiological analysis of soils, the soil population, transformation of nitrogen, transformation of organic matter, soil biology from an agronomic standpoint, etc.

COMMISSION IV

SOIL FERTILITY

In the absence of Dr. E. A. Mitscherlich, Germany, Dr. M. Trénel, Secretary of Commission IV, presented a general report of the commission's activities since the Rome meeting:

GENERAL REPORT OF THE FOURTH COMMISSION

DR. M. TRÉNEL

Herr Prof. Dr. E. A. Mitscherlich, den ich zu vertreten die Ehre habe, ist zu seinen grossen Bedauern leider verhindert, am Kongress beizunehmen, auch Herrn Zylstra dem Vice-Presidenten war es nicht möglich, hier zu erscheinen. Da O. Arrhenius in Java weilt, bin ich als einziges europäisches Mitglied übrig geblieben. Ich hatte mit Mitscherlich gewunscht, dass Prof. Hoagland den Bericht hatten sollte; Prof. Hoagland hat jedoch abgelehnt.

In der Sache ist nicht sehr viel zu berichten. Seit Rom sind wir einmal zusammengekommen und zwar am 21.9.26 in Düsseldorf anlässlich der Tagung deutscher Naturforscher. Die Sitzung brachte keine Klarheit über die zur Diskussion stehende Fragen; sie konnte auch keine bringen, weil die Probleme der IV Commission wohl die schwierigsten sind, die die Bodenkundliche Gesellschaft interresieren. Wir wissen zu wenig über den inneren Chemismus der Pflanze. Das ist wohl der Grund, dass Sie, meine Herrn, in den Düsseldorfer Beschlüssen, alle Methoden gennant finden, die für die Bestimmung der Nährstoffbedärfs in Frage kommen; das sind:

(1) Feldversuche
(2) Gefässversuche
(3) der Keimpflanzenversuch nach Neubauer-Schneider

Wie Ihnen wohlbekannt ist, gibt Mitscherlich dem Gefässversuch mit mathematischer Auswertung den Vorzug. Wie Ihnen weiter wohlbekannt ist, wird gerade das Wachstumsgesetz von Mitscherlich in Deutschland heftig angegriffen. Ich Selbst habe hier nur ein Amt und keine Meinung; ich bin jedoch der Aussicht, das diese Probleme nich durch Diskussionen sondern nur durch experimentelle Arbeit daheim der Lösung näher gebracht werden können.

Als 2 Frage steht die "Bestimmung der auszuwendenden Düngemittel und der Kalkgabe durch die Pflanze" zur Diskussion, und als 3 Frage "der Einfluss der Bodenbearbeitung auf der Ernteertrag." Ausserdem soll die Bedeutung der Stimulantien besprochen werden. Um die Einheitlichkeit insbesondere der Feldversuche zu gewähr leissten soll durch einen Unterausschuss ein Fragebogen mit genauer Anweisung zur Ausstellung der Versuche aufgestellt werden.

Die Lösung der Probleme, die die IV Kommission interessieren, die Steigerung der pflanzlichen Producktion, bedeutet die Lösung der brennendsten Frage überhaupt der Frage, wielange die Menschen friedlich nebeneinander leben können. Wenn Sie diese Frage lösen brauchen Sie keinen Völkerbund. In diesem Sinne überbringe ich die Grüsse des Presidenten der IV Commission an seine Amerikanischen Kollegen und wünsche, dass der I Internationale Kongress ein Kilometerstein sei auf dem schwierigen Wege zum Volkerfrieden.

COMMISSION V

CLASSIFICATION, NOMENCLATURE AND MAPPING OF SOILS

Dr. C. F. Marbut, United States, presented the following report of previous meetings and of the work of Commission V since the Rome Conference:

GENERAL REPORT OF THE FIFTH COMMISSION

DR. C. F. MARBUT

The Third International Pedological Conference met in Prague, Czechoslovakia in April 1922. As part of its work, it created two International Committees designated as the Fourth and Fifth and assigned to them the task of handling matters concerned with soil classification, nomenclature and mapping. The Fourth Committee, called the Committee on the Classification and Nomenclature of Soils, was placed in charge of Dr. B. Frosterus of Finland and the Fifth, called the Committee on the Cartography of Soils, was placed in charge of Professor G. Mürgoci of Roumania.

The chairmen of both committees were very active and each presented to the Fourth International Conference at Rome, in April 1924, an elaborate printed report. Each report consisted of a series of papers from persons engaged in Soil Classification, or Soil mapping, in most of the countries of the world where such work is being performed. The chairman in each case presented a summary of the various papers and made certain recommendations.

The recommendation of the Fourth Committee with which we are concerned, one proposed and adopted during the committee meetings in Rome is as follows: "That the committee recommend to all persons in all countries the study, until the meeting of the next International Congress of Soil Scientists, of soil *profiles* and the accumulation of as much data as possible on the subject, in their respective countries, to the end that a scheme of soil classification, based on these features, may be devised."

The recommendation of the Fifth Committee with which we are also concerned is as follows: "That soil specialists in all countries be urged to

accumulate data, each in his own country, that may serve for the construction of a reconnaissance soil map and transmit this to the chairman of certain committees to be organized for that purpose, one for Europe and Asia, and another for the Americas, in order that these committees may prepare, for presentation to the Fifth International Congress of Soil Scientists, such map as the data will warrant."

At the Fourth Conference in Rome it was decided to merge the Fourth and Fifth committees into one to be designated as the Fifth Committee and known as "The Committee on the Classification, Nomenclature and Mapping of Soils." This Committee is charged with the duty of carrying out the recommendations made by the old Fourth and Fifth Committees and carrying forward the various lines of work with which they were charged from where each was left at the close of the Rome Congress.

A circular was sent to soil workers in various countries for the purpose of urging them to devote as much time as conditions would permit during the seasons of 1925 and 1926 to the accumulation of carefully drawn descriptions, sketches and photographs of typical soil profiles. Where these can be supplemented by samples, however small, collected from each soil horizon this should be done. All this data should be sent to the chairman of the Committee on Soil Classification, Nomenclature and Mapping, Mr. C. F. Marbut, Bureau of Soils, Washington, D. C., U. S. A.

The exact location of every profile should be given and as much geographic data regarding the region as can be given in a page or two of manuscript should accompany the data.

The text should be written very plainly in the native language of the writer or in French, German or English. When laboratory data is available it should be sent also.

It may be advisable to say that there are no funds available for the payment of expenses of any kind. The field work will be done in connection with the regular duties of the various workers so that the expenses can in most if not all cases be limited to small sums for postage.

In mapping the soils in any region, however large or small, it is necessary to define the units of mapping, the soil types or groups of types, according to a uniform series of criteria. A soil map of the two Americas, if it have any scientific value, must show soil types that have been constructed from the same point of view, though the same degree of differentiation need not be maintained throughout. The latter will depend on the extent to which the soils have been studied in the several countries.

COMMISSION VI

THE APPLICATION OF SOIL SCIENCE TO LAND CULTIVATION

Dr. J. Girsberger, Switzerland, presented the following report of the preliminary meeting of Commission VI:

GENERAL REPORT OF THE SIXTH COMMISSION

DR. J. GIRSBERGER

BERICHT ÜBER DIE TÄTIGKEIT DER 6. KOMMISSION

ANWENDUNG DER BODENKUNDE IN DER KULTURTECHNIK SEIT DEM KONGRESS IN ROM

Die Tätigkeit der 6. Kommission war einerseits organisatorisch, anderseits individuell—fach-technisch.

Die Kommission wurde eigentlich erst in Rom gegründet. Es war dann die erste und Spezialaufgabe des Sprechenden, für die 6. Kommission Mitglieder zu werben. Teils geschah es durch persönliche Werbearbeit seitens der Vorstandsmitglieder, teils durch ein Werbeschreiben, das im September 1925 in den "Mitteilungen der Internationalen Bodenkundlichen Gesellschaft" erschienen und vom Herrn Generalsekretär, Dr. Hissink, gegengezeichnet worden war. Dieses Werbeschreiben hatte guten Erfolg. Die Kommission zählt heute ca. 120 Mitglieder. Ich hoffe, dass sich die Zahl noch bedeutend vermehren werde und dass durch den gegenseitigen Verkehr unter denselben ein reger Gedankenaustausch sich anbahne, wie dies erfreulicherweise schon bisher der Fall war, sowohl zwischen den einzelnen Mitgliedern mit dem Präsidenten, wie unter sich.

In Bezug auf die fachtechnischen Arbeiten ist zu bemerken, dass sie sich zur Hauptsache individuell gestalteten, d. h. dass sie zumeist von den einzelnen Mitgliedern für sich gepflegt wurden. Eine Zusammenkunft der Kommission konnte leider nicht stattfinden, da die Mitglieder derselben einerseits zu weit auseinander wohnen und bei ihrer durch die Praxis stark in Anspruch genommenen Zeit die Musse für eine Konferenz nicht fanden. Ausserdem waren verschiedene Mitglieder durch andere Kongresse schon in Anspruch genommen. Eine Zusammenkunft ist nun für das nächste Jahr geplant; das Programm dafür ist noch nicht weiter gediehen.

Die Kommission hatte anlässlich ihrer Beratungen in Rom im Jahr 1924 für die wissenschaftliche Betätigung ihrer Mitglieder insbesonders folgende Themates aufgestellt:

1. Die Arbeitsweise des pedologischen Dienstes.
2. Die Organisation des Meliorations-Versuchswesens.

3. Gewinnung von Erfahrungen über den Einfluss der Meliorationen auf die verschiedensten Bodentypen.
4. Bekanntgabe der Erfahrungen im kulturtechnischen Versuchswesen.

Die Punkte 1, 2 u. 3 haben ihre einlässliche Bearbeitung gefunden. Ueber die "*Arbeitsweise des pedologischen Dienstes für die* Landeskultur" sind unserm Congress folgende Arbeiten eingesandt worden:

(1) *Baurat Spišek in Brünn:* "Die Organisation des pedologischen Dienstes in der Tschechoslovakei."

Der Vortrag liegt bei den Akten des Congresses; der Auszug ist unter den gderuckten Abstracts enthalten.

(2) *Baurat Gazdik in Bratislava:* "Ueber die Organisation des Forschungswesens auf dem Gebiet der Kulturtechnik." Auch hiefür sind die Unterlagen dem Congress eingegeben.

Ueber das Meliorationsversuchswesen orientieren die Vorträge von

(1) *Baurat Gazdik* (siehe vorerwähnten Vortrag) und von

(2) *Oberbaurat Otto Fauser* in Stuttgart über: "Das Drainageversuchswesen."

An Hand dieses Vortrages soll nachgewiesen werden, wie ins künftig dem 4ten Programmpunkt unserer Resolution von Rom intensiv nachgelebt werden kann.

Den 3ten Punkt dieser Resolution, die "*Allgemeine Bekanntgabe der Erfahrungen über den Einfluss der Meliorationen auf die Bodentypen*" Abhandeln die wissenschaftlich streng fundierten Arbeiten von

Dozent Dr. Rudolf Janota in Prag

(1) "Ueber die Wirkung der Drainagen auf die verschiedenen Böden."

(2) "Ueber die Tiefe der Draingüge in den verschiedenen Bodentypen."

Diesen Referaten dienten vielfache Korrespondenzen teilweise auch mündliche Besprechungen unter einzelnen Mitgliedern unserer Commission.

Das ist die Tätigkeit während der abeglaufenen 3 Jahre.

Es darf beigefügt werden, dass von Liste des Präsidenten vielfache Arbeit geleistet werden musste auf den Congress hin, namentlich wurde, wieder auf Grund einer allgemeinen Umfrage, unter den Mitgliedern der 6. Kommission im Programm für die grosse Exkursion die unserem heutigen Congress folgen soll, entworfen. Nach dem uns vorgelegten Reise programm hoffen wir ein reiche Belehrung auch auf unserem Gebiet erfahren zu dürfen.

Dazu kam ferner seitens des Präsidenten der Kommission die allgemeine Propaganda—Tätigkeit für die "Internationale Bodenkundliche Gesellschaft." Ein Vortrag hieruber ist sämtlichen Kommissionsmitgliedern zugesandt worden.

Was die zukünftigen Arbeiten der Kommission anbelangt, wird ganz besonderer Wert gelegt werden müssen auf die Versuchstätigkeit und auf die allgemeine Bekanntgabe der gewordenen Resultate.

Es ist zu hoffen, dass uns hiefür die "Mitteilungen der internationalen bodenkundlichen Gesellschaft" wirksame Hülfe werden angedeihen lassen und uns damit in nusern Bestrebungen wirksam unterstützen.

PRESIDENTIAL ADDRESS

The President of the Congress, Dr. J. G. Lipman, next addressed the assembly chosing as his subject "Soils and Men."

SOILS AND MEN

Dr. J. G. Lipman

Seven thousand years of recorded history seem like fleeting moments against the background of terrestrial time. They are the last chapters of a long story in the course of which continents arose out of the sea only to be planed down and to arise again. In the course of that story there came to be long periods of aridity and glaciation; of clear, balmy skies and of cruel, biting cold. A billion years of changing topography, of continental grouping, of land bridges and of vanishing inland seas left their impression in the earth's crust. An almost endless succession of plant and animal societies came into being and disappeared ere man groped his way out of the darkness. He is a newcomer in the vast scheme of unfolding creation, a newcomer as judged by the astronomer, the geologist or the biologist. But when measured by the standards of anthropology, ethnology, philology, archaeology and human tradition he is the child of a remote and forgotten past. He has been in many places, he has felt much and has suffered even more. High table lands, alluvial plains, dense forests and vast marches form a part of his subconscious experience. From all of these he has absorbed something that clings to his spirit like the echo of a thousand environments, of space and time without end. Truly, in his upward climb he has accomplished the seemingly impossible; or, as Goethe has expressed it: "Nur allein der Mensch vermag das Unmögliche."

But much as the student of soils may be tempted to ponder on man's past, he must leave this to the philosopher and the poet. It is his task, rather, to inquire into the relations of climates, soils, plants, animals and man. This may seem like a large undertaking. Indeed, most soil investigators find it expedient to deal with soils as such, and usually with only a single group of soil problems. For all that, soil science must build a foundation large enough and strong enough to support the study of plant food resources and their mobilization, of the inter-relations of soil

and plants and of soil characteristics and peculiarities as reflected in the make-up of plants, animals and man.

We find frequent reference in folk songs and legends to Mother Earth and her bounty. In partaking of this bounty her children remove from the soil a part of its fertility. This process of removal cannot go on forever without ultimate disaster to the land and to the people dependent upon it. It is not easy to forget the passionate denunciation of Liebig of what he called exploitation, nor his plea for soil conservation. He tells us that: "The sewers of the immense metropolis of the Ancient World, engulfed in the course of centuries, the prosperity of the Roman peasant; and when the fields of the latter would no longer yield the means of feeding her population, these same sewers devoured the wealth of Sicily, Sardinia, and the fertile lands on the coast of Africa."[1] A picture no less dark is painted by Prothero.[2] In describing mediaeval agriculture in England says: "There was little to mitigate, either for men or beasts, the horrors of winter scarcity. Nothing is more characteristic of the infancy of farming than the violence of its alterations. On land which was inadequately manured, and on which neither field-turnips nor clovers were known till centuries later, there could be no middle course between the exhaustion of continuous cropping and the rest cure of barrenness."

The statements just quoted may well indicate that the stability of human society is vitally affected by the supply of soluble salts in surface soils. The geological origin of the soil material will determine the potential supply of soluble salts. Climatic factors, particularly rainfall and temperature will determine the rate of rock decay, the removal of soluble salts by leaching, the accumulation and decomposition of organic materials. Human agencies may and do disturb the balance of Nature's forces, and one generation of mankind, in providing itself with food and shelter, will appreciably influence thereby the fortunes of the succeeding generation. The cutting down of forests, the ploughing of prairies, drainage and irrigation, the stirring of the surface soil with tillage implements and the removal of plant and animal products from the land will tell their story in no uncertain terms.

The disastrous effects of erosion are commonplace knowledge to all students of soils. Their dramatic significance expressed in the more or less permanent destruction of vast stretches of agricultural and forest land is not so well known to the layman. The washing out of soluble salts from humid soils unprotected by plant cover and the additional drain of plant-food ingredients by the sale of crops and livestock, when not counteracted, must be followed by economic and social stagnation. In arid regions adequately supplied with irrigation water the rise and accumulation of alkali salts may compel the abandonment of large areas

[1] Letters on Modern Agriculture, London, 1859, p. 229.

[2] English Farming Past and Present, London, 1917, p. 33.

of once fertile land. Altogether the diminishing yields from the land may be attributed more directly to one or more factors. These will include deterioration of texture and structure, the accumulation of acidity, the loss of organic matter and of the ash ingredients of plants, the concentration of toxic substances in the surface soil and the slowing down of microbiological activities.

Simple as are the facts just noted they are still calling for systematic study in their bearing on the rise and fall of nations. They are still to be interpreted in terms of human progress—political, social and economic. We are indebted to Hilgard for pointing out clearly and forcefully [1] that as human societies came and went, as civilizations followed one another humid regions were found to be less satisfactory than arid regions for assuring stability and permanence to organized society. He concludes that: "In humid countries, as is well known, cultivation can only in exceptional cases be continued profitably for many years without fertilization. But fertilization requires a somewhat protracted development of agriculture to be rationally and successfully applied in the humid regions, and the German tribes, like the North-American Indians, seem to have shifted their culture grounds frequently in their migrations. No such need was felt by the inhabitants of the arid regions for centuries, for the native fertility of their soils, coupled with the fertilizing effects of irrigation water bringing plant-food from afar, relieved them of the need of continuous fertilization; while in the humid regions, the fertility of the land is currently carried into the sea by the drainage waters, through the streams and rivers, causing a chronic depletion which has to be made up for by artificial and costly means. The arid regions were, therefore, specially conducive to the establishment of the highly complex polities and high culture, of which the vestiges are now being unearthed in what we are in the habit of calling 'deserts,' the very sands of which usually need only the life-giving effects of water to transform them into fruitful fields and gardens."

But while it is true that ancient societies found in arid regions a greater measure of permanence; while they recognized the more enduring quality of arid soils, they also evolved empirical methods of soil treatment that are widely applicable to arid and humid soils alike. It has now become the task of the physical and biological sciences to give intelligent direction to agricultural practices, both ancient and modern. These sciences have opened broad vistas of production. They have shown how humid soils may be guaranteed a long life, if not immortality. We can now measure with some degree of accuracy the qualitative and quantitative relations of soils, plants and animals. We know the sources of raw materials for correcting the deficiencies of soils and for increasing their productive power. Indeed, we have developed a new conception of what is com-

[1] Soils, pp. 417–421.

monly called plant-food, and of its use and conservation. Many years ago Liebig paraphrased a statement by Albrecht Block as follows: "A farmer may sell and permanently alienate all that portion of the produce of his farm which has been supplied by the atmosphere—a field from which something is permanently taken away, cannot possibly increase or even continue equal in productive power." [1] The more modern view was recently expressed by William J. Hale. He said: "When we contemplate the science of agriculture we are forced to define an agriculturist as an organic chemical manufacturer." [2]

Being an organic chemical manufacturer the farmer must have his raw materials. These he finds in the soil and in the air. Not content with that, he must know the potentialities of his land when the store of raw materials in the soil is supplemented by outside supplies of plant-food, and, perhaps, when the normal precipitation is augmented by irrigation water. As a manufacturer he must study the economics of plant and animal production, the changes in his plant-food inventory, luxury consumption and crop quality as influenced by the composition and treatment of his soil. As a manufacturer he must recognize that he and others like him have a community of interest and that such interest transcends natural and political boundaries.

The producing of animal and human food does not represent the entire responsibility of those who till the soil. To be sure, they are primarily employed in the task of transforming certain simple chemical substances into complex organic compounds. But they are also engaged in creating something less ponderable, something of large value as measured in terms of human understanding. For instance, it is common knowledge that soils, plants and animals represent an accumulation of carbon and nitrogen that, at one time or another, constituted a part of the atmosphere. The carbon and nitrogen in soils are present in compounds of varying age. Indeed, some of the organic matter in subsoils is of very ancient origin. The carbon and nitrogen of vegetation are found both in the most delicate annuals and in the centuries-old redwoods. The carbon and nitrogen of living animals represent relatively recent transmutations of plant materials. But the residues of ancient floras and faunas contain something that was withdrawn from the atmosphere a very long time ago. We become convinced of this as we examine the entire range of carbon carrying materials from vegetation, peat, lignite, soft coal, anthracite to some of the graphitic minerals.

Let us consider, briefly, some of our important sources of carbon in order that we might gain a clearer perspective of past, present and future relations of soils, plants and animals. The following table will help, perhaps, to reflect some of these relations.

[1] Letters on Modern Agriculture, London 1859, p. 175.

[2] The Dearborn Independent, October 2, 1926.

Certain Carbon and Nitrogen Resources

	Carbon Tons	Nitrogen Tons
Atmosphere [a]	600,000,000,000	
Soils	400,000,000,000	40,000,000,000
Forests	110,000,000,000	592,000,000
Peat	63,000,000,000	3,620,000,000
Coal	6,360,000,000,000	98,000,000,000

[a] The quantity of carbon in sedimentary rocks is estimated to be about 30,000 times as great as that in the atmosphere. Clarke, The Data of Geochemistry, 4th ed. p. 48.

By way of passing comment we need merely note that soils and plants, ancient and modern, are a vast reservoir of both carbon and nitrogen potentially usable in the development of living organisms.

Let us compare now the data relating to the content of carbon, nitrogen, phosphorus and potassium in soils, forests and the animal and human population of the earth. We find the following:

The Quantities of Carbon, Nitrogen, Phosphorus and Potassium in Soils, Forests and Animal and Human Populations

	C Tons	N Tons	P_2O_5 Tons	K_2O Tons
Soils	400,000,000,000	40,000,000,000	40,000,000,000	600,000,000,000
Forests	110,000,000,000	592,000,000	93,000,000	260,000,000
Animals	87,000,000	9,000,000	6,000,000	660,000
Human Population	10,000,000	2,000,000	1,500,000	260,000

Crudely approximate as are these figures, they may be adequate for calling our attention not alone to certain quantitative relations but also to the process of manufacturing substances that become a part of the life of human generations. These raw materials together with calcium, sulfur and other elements or simple compounds must be utilized intelligently and effectively, and in such utilization soil science can offer helpful guidance.

There is a more or less definite relation between man in his physical and mental makeup and his soil environment. Systematic studies are still lacking on the part that soils have played in the past and are now playing in determining the peculiarities of races and of individuals. We do know that there is a very considerable range in the composition of plants. Soils which supply readily available and abundant quantities of nitrogen and of ash ingredients usually produce plants containing a relatively high proportion of these constituents. Furthermore, the nitrogen and ash content of animal and human foods have a direct effect on the growth and development of both animals and men. It would not be improper, therefore, to assert that food in its quantity and quality finds expression in terms of human quantity and quality. The supply and

quality of food have made themselves felt in the currents of human history. They have influenced race and national land legislation and policies. Because of this, the student of soils is often tempted to analyze, if not to determine, the significance of soils as a factor of human history. The time may come when our knowledge on this score will be ample enough and accurate enough to give us a proper perspective.

In earlier days people of different regions lived in comparative isolation. There was a limited interchange of ideas and a still more limited interchange of commodities. The individual farmer tried to be self-sufficient as did also the countries to which he belonged. Food eaten in any region was almost exclusively of local origin. Hence, there was, prior to the beginning of the 19th century, a more limited flow of food products from the farm to the city and from country to country. The cities themselves were, in a measure, overgrown villages, and a not inconsiderable portion of the food consumed in them was obtained in the city gardens or those located in the immediate outskirts. Under such conditions, the differences of soil composition were more sharply reflected in the food supply of the different communities. Such sharp distinctions are still being felt over a large portion of the earth's surface. It is true, at the same time, that into the large modern cities there is constantly being brought food from many places, some of them located at great distances. By way of illustration it may be noted that New York City obtains much of its fruit from the Pacific Coast, butter and other dairy products from the middle west, meats from the Mississippi Valley, wheat from the northwest, vegetables and poultry products from the Atlantic Seaboard. It obtains its food supplies from practically every soil province in the United States, but not content with that it pleases itself to put in its larder food commodities from Europe, Asia, Australia, Africa and South America. For this reason, the residents of New York City, as well as those of other large cities, have developed a more mixed diet containing in varying degrees proteins, carbohydrates, fats, vitamines and ash constituents. It is the business of soil science to familiarize itself with imports and exports of agricultural commodities insofar as they have a bearing on soil fertility in different regions. There is a certain responsibility that soil science has in maintaining contacts with the progress of industry and transportation since these play a part in the movement of agricultural commodities, and, because of that, have a not too remote connection with crop sytems, and soil practices in all countries. It would not be too much to say that economic, political and social trends are based, in a measure, on land and soil resources. The resources of soil science may, for this reason, be used effectively in giving proper direction to the solution of important problems.

In a more immediate way soil science has definite responsibilities in indicating rational and effective methods of land utilization. As students

of soils, we recognize the need of standard methods of soil investigation as well as of soil classification and mapping. Be it said to the credit of the predecessors of this Congress that much has already been accomplished at international soil conferences. It is hoped that the task will be completed in the not distant future. When that time comes, economists as well as land owners will know in a more concrete way the potentialities of the different soil regions and the methods that should be followed in securing maximum economic production. By establishing standard methods of soil classification and study, we shall hasten the development of a sound program of land utilization in all countries. We shall provide then for the intensification of production and the support in greater comfort of the growing population of the world. It is the duty of soil sciences to establish more clearly the relation of crops to soils in order that cropping methods may best conserve plant food, solar energy and human labor. Soil science should teach the farmers how best to modify food quality by soil treatment. It should plan a more far reaching program of research and education in order that it might serve in a constantly larger way the needs of a human society that from year to year is growing more complex in its organization and more exacting in its demand for such of the products of the land as are essential for maintaining the moral and spiritual values that are the final measure of human activities.

Thus we come to the world-wide problem of plant, animal and human food. As students of soils and soil resources we must think not only of plant-food but of its mobilization. We must consider the soil solution not alone in its local relations, but as a part of a great mass of fresh water moving to the sea. We must consider the cubic miles of sediment deposited at the outlets of great rivers as a toll upon the land and as a tax on those who till it. We must include in our reckoning the circulation of carbon, hydrogen, nitrogen and sulfur as affected by combustion, decay and fermentation. We must think, finally, of ancient plants and animals, as well as of those now living, as possessors of something that in the workshop of creation must be used over and over again. We are the technical advisors to the nations who are trustees of precious raw materials. These must be used wisely and conserved effectively in order that human kind may travel with the least pain and sorrow on its road of destiny.

The presidential address was followed by a brief address by Mr. C. H. MacDowell of Chicago:

SOILS AND FERTILIZERS

C. H. MacDowell

The proper utilization of plant foods is a most important division of soil science. Plant foods are added to soils to increase the production

of crops and to improve their quality. The results of their use are influenced by the crops to which they are applied, the forms and quantities used, by the manner of application, by variations in climate, and to a great extent by the composition and condition of the soil. Their proper use therefore varies with crops, mode of application, type of soil and climate or weather.

The need of plants for added nutrients is determined by economic factors—by money crops and cost of production. Within limits, the cost of production varies inversely as the yield per acre. Larger yields per acre result in lower cost; lower cost increases profits—decreases losses.

Chemicals Help Control Yield

There are many hazards in farming: to insure success the margin of safety must be large. Weather, pests, yield, quality, fluctuating markets all directly influence the return. A greater knowledge on the farm of the means by which these factors can be more effectively controlled would reduce the hazards. It is the function of the soil scientist and practicing agronomist not only to study these factors and their control but to interpret the results of his study simply and practically to the farmer, who can best be instructed by the teachings of the unbiased. Much as the fertilizer industry would like to help him, try hard as it may, its recommendations are often looked upon as not entirely disinterested.

Among the means of controlling yield, agricultural chemicals play a large and effective part. The world has ample supplies of available raw material for making these chemicals. Considered from a national point of view, the location of the raw materials is not altogether satisfactory. Europe is dependent on North Africa, America and islands of the Pacific for materials for the productions of soluble phosphate. Germany and France control most of the potash, although California is winning a large and increasing tonnage of exceptionally high-grade potassium chloride. Spain has developed a producing potash mine, and Poland is exploiting her potash deposits. Chile controls natural nitrate nitrogen and, with the reduction or removal of her export tax, an artificial trade barrier, and with improvements in the technique of recovery already under way, she may regain the position she lost through high pricing and the consequent displacement of her product by other inorganic forms of nitrogen. By-product coke and gas plants are increasing in number and in output of ammonia liquor and sulfate of ammonia. These plants are widely distributed and provide supplies near points of consumption. The remarkable forced development of nitrogen-fixation, with its significant influence on the world's future and with its flexibility as to place of manufacture, insures an ample future supply of nitrogen.

Higher Analyses Now Used

There has been little increase in the sale of fertilizer in the United States since 1914. Somewhat higher analyses are now used. Accurate figures showing the annual consumption of fertilizers are not available, but it is estimated that it amounts to 7,500,000 tons, of which 6,750,000 tons are bagged superphosphate and mixed fertilizer, the remainder being nitrate of soda, sulfate of ammonia, potash and vegetable meals.

Ample resources of sulfate and pyrites, supplemented by larger recoveries of sulfuric acid from zinc and copper smelters, assure the fertilizer industry an abundant supply of sulfur. We have large reserves of phosphate rock, which are easy of access by water and rail. Ammonium phosphate and triple superphosphate are being manufactured in considerable quantities. Ammonium sulfate is produced at coke and gas plants in excess of the domestic demand and much of it is being exported. Several small plants are now producing synthetic nitrogen, which, however, has not yet entered the fertilizer field. One large plant now under construction will produce fertilizer nitrogen for the domestic and export trade.

Complete Fertilizers in Demand

American fertilizer practice has developed along definite lines, and the industry has been shaped to meet the need. The procedure has been, first, to supply some outstanding major deficiency, as by the use of bone meal and superphosphates alone, on such of our soils are deficient in phosphorus; second, to apply in comparatively small amounts the properly balanced complete plant ration to the immediate feeding range of the roots. The largest demand is for complete mixed fertilizers containing the three recognized essential ingredients—nitrogen, phosphorus and potassium. The American Farmer feeds his crops mainly with a complete balanced ration for two reasons—first, the evidence points to greater effectiveness when the three essentials are used together in definite ratio and in the same root-growing area; second, under American methods and conditions of farming it is cheaper to give one application of complete fertilizer to obtain maximum results. The quantity of fertilizer used in the United States, if stated in pounds per acre, is misleading when it is compared with the quantity used in Europe on account of the comparatively low grades heretofore used in this country.

Look to Soil Scientists

Although the use of mixed fertilizers is well established, the types and grades are now undergoing revision as new and more concentrated materials become available. The development of these materials not only marks vast strides in chemical manufacture but has brought about

important economic changes, with attendant problems that confront the American fertilizer manufacturer and consumer. In consequence of these changing conditions the industry now turns to the soil scientist for advice, guidance and approval in the use of these materials. The agronomists must determine the facts and assume the responsibility for making definite recommendations as to the kinds and quantities of fertilizers that may be more profitably employed. The custom has been to use superphosphate, crude potash salts, and nitrogen compounds obtained from organic and inorganic materials. The mixtures produced have been of comparatively low analysis—many of them unnecessarily low—but they have carried several chemical elements besides the three essentials that have played their part in making the fertilizer effective.

In the human dietary, fat, protein and carbohydrate are not sufficient for health, strength and normal growth. People are interested in the content of lime, phosphate, and iodine in their food, as well as in its roughage, bulk and digestibility. A highly refined concentrated table diet is not satisfactory. Just so with plants. Deficiencies occur in their diet in respect to elements other than nitrogen, phosphorus and potassium. Sand-drown of tobacco without magnesium and inferior under-flavored pineapples without manganese are examples. Calcium, sulfur, iron, sodium, silicon and other elements must be available to plants in suitable form. It rests with the soil scientists to tell us when the natural supply of these elements is too low, when they should be included in fertilizers, and in what ratios they should be included to give the best results.

The use of fertilizer chemicals enables the farmer to control better his growing crop. By proper selection he can start growth more quickly; by the use of solely mineral ammoniates he can greatly influence the length of the growing period; by using potash he can grow profitable crops on black muck and peat soils that have heretofore been non-productive, and he can hasten maturity by the proper use of phosphorus.

Corn Belt Needs Phosphorus

It is the American practice to use larger proportions of phosphoric acid in mixed fertilizer than those indicated by the crops and residues or than those ordinarily used in Europe. It may be that this apparently excessive supply of phosphorus stimulates heavier, earlier fruiting if used in the presence of other nutrients. Many field trials show that fertilizer can be so prepared as to insure larger yields and earlier maturity than can be obtained by using fertilizers of standard types. Early crops get the benefit of the early spring rains and materially diminish the hazards arising from dry weather and pests, and especially they often enable the planter to obtain higher prices for his product.

The soils of the Corn Belt are naturally deficient in certain mineral

elements, and continued cropping without replacement of these elements has still further depleted them. One great trouble in the Middle West is so-called "soft corn"—that is, immature, unripened, over-moistured corn at harvest time. Phosphorus applied in considerable quantity during the growing season helps to prevent the formation of soft corn, and by hastening maturity minimizes the danger from frost. By the use of phosphorus frost early in the fall is made less of a hazard, and frosts late in the spring may be made harmless, as a well-fertilized plant may stand several degrees more frost than an undernourished one, the chemical concentration of the plant juices lowering their freezing point.

Fertilizers Have Secondary Effects

But aside from furnishing plant food fertilizers have certain notable secondary effects. They influence both the physical condition of the soil and the physico-chemical condition of the soil solution. Advocates of a new practice favor the use of easily soluble high-analysis salts as fertilizer materials. Great care must be exercised, however, in their distribution in the soil else the result of their use will be a concentration of electrolytes in the soil solution and a consequent tendency to dehydrate the seed by osmosis and to prevent its satisfactory germination. Before the new practice can become general, modifications must be made in fertilizer-distributing machinery. The distribution of fertilizer in solution may become practical for certain crops or in certain areas. Here the agronomist must coöperate with the engineer. Soluble plant poisons, such as chromium, vanadium, boron or arsenic derived from smelter by-product sulfuric acid, may concentrate in the soil solution and retard or prevent germination, whereas their presence in minute amounts may be harmless or at times even beneficial. Even the use of a highly soluble low-grade potash salt, such as kainit, has at times made trouble by causing the concentration of undesirable elements in the soil solution.

The effect of the use of fertilizers of certain chemical composition upon the colloidal condition of the soil must be considered. A very slight change in the chemical composition of the fertilizer may make a very great change in the physical constitution of the soil. Present-day fertilizer materials, such as ammonium sulfate and sodium nitrate, leave definite residues in the soil. Calcium sulfate tends to flocculate certain types of soil and is used for that purpose. Superphosphate is a large carrier of calcium sulfate. Lime tends to correct the colloidal condition of clay soils; but does the magnesia in dolomitic limestone have the same effect?

By contrast, the new materials such as ammonium phosphate, ammonium nitrate, potassium nitrate and urea, would leave little or no residues in the soil. What, then, would be their ultimate effect upon its physical condition?

Is Organic Nitrogen Really Best?

Organic matter greatly effects the physical nature of the soil. Barnyard manure, crop residues and plowed-under crops furnish the necessary humus. The amount of humus that can be carried in a fertilizer is too small to be of much consequence in supplying the usual requirements. The organic materials in a fertilizer are essentially carriers of nitrogen, although they are also valuable as conditioners. To make this nitrogen effective, bacterial action and a series of chemical changes are necessary. May it not be that the reported superiority of organic forms of nitrogen, as shown by the earlier experiments, reflected in a measure the safety with which this type of fertilizer could be concentrated around roots, and even in immediate contact with germinating seed? Inorganic soluble nitrogen is more readily available and is distributed more easily by soil moisture, so that it must be more carefully placed with reference to the location of seed and the movement of soil water. The fertilizer manufacturer pays a substantial premium for organic nitrogen. The farmer instinctively favors this form. Much of it is especially valuable for raising crops for feeding animals. Europe exports to the United States her surplus organic nitrogenous material, which is largely derived from industrial waste. Such organic by-products and wastes as are not more valuable for other uses will be shipped for use in fertilizers to points that lie within a certain geographic radius from the place of production, but the desirability of paying any considerable premium for such products is at least debatable. Their use may be advisable for crops like tobacco and certain fruits, whose quality or flavor seems to be improved by their employment. Further research as to the soundness of this premise is desirable.

The demand for nitrogen for use on general field crops in the United States has grown slowly. Agronomists, more particularly those in the central West, have recommended the planting of legumes in rotation to maintain nitrogen in the soil, but they have been disposed to confine their recommendations to special crops. There has been little call for a fairly high content of nitrogen in fertilizers for cereals. Pastures are seldom directly fertilized with nitrogen or with complete fertilizer, so that an extremely effective and economical method of feeding stock is not employed. In many dairy regions manure is returned to grass and tilled lands, but little effort is made to balance nitrogen with mineral nutrients. It has been difficult to persuade the farmer that he could profitably use considerable quantities of nitrogen in mixed fertilizers that are applied to general farm crops. Higher unit content of nitrogen would materially cheapen the cost of nitrogen per pound on the farm, and on most soils, would reduce the cost of growing crops.

The remarkable development of nitrogen-fixation, with its significant

influence on the world's future, is opening up a new field of chemical adventure in the manufacture of fertilizer. Highly concentrated nitrogen compounds are now becoming available. As the development of nitrogen-fixation proceeds, what will be the trend in type of product? Synthetic ammonium sulfate adds to the output of a material that is already produced in large quantity. Ammonium phosphate is not a new material. Leunasalpeter makes practical the moderate use of ammonium nitrate and its use seems to mark an advance in the art. Calcium nitrate is a standard product. Urea, a valuable nitrogen carrier, does not blend well with superphosphates. Urea phosphate is unknown to American manufacturers of fertilizer.

Higher Analysis Goods Require Research

New types of complete fertilizers of exceptionally great concentration are coming on the market. Chemically they seem to be soluble compounds of ammonium phosphates, ammonium chlorides, and ammonium and potassium nitrates. Their manufacture requires central assembling of the phosphorus, potassium and nitrogen-bearing constituents, as does the manufacture of fertilizers of other grades, so the advantage or disadvantage of preparing them at the plant is dependent on the yield obtained from the raw materials and the cost of their combination and their reduction to shipping form. If the cost is as great as or greater than that of manufacturing and mixing superphosphate or triple superphosphate with concentrated nitrogen and potassium-bearing materials, the only possible economy in making them is a greater saving of freight from plant to point of consumption. More concentrated mixtures, made with materials now available, carrying any desired ratio of nutrients, can be manufactured and can be used with economy. The soil scientist should determine whether greater concentration, with certain eliminations of carriers, some containing plant food and soil improvers, is an advance in the art of fertilizing, and whether greater local concentration of soil solution is a practical factor. Higher analysis calls for smaller applications per acre at any determined rate of enrichment. The highly concentrated mixtures are likely to be more hygroscopic than those of lower concentration and are more difficult to distribute uniformly than properly prepared forms of the types now used. What effect will these more concentrated mixtures have on the sale of present-day types? Have they any special value that is not possessed by the types now generally used? Is the competition between the two types to be based on cost only? Will the present methods of manufacture be gradually discontinued, and will solution and double decomposition mixings take their place? What additional elements will be added to commercial fertilizers?

Scientists Must Lead the Way

Some of the facts to be considered in any attempt to answer these questions are economic. The soil scientist and agronomist must show us the way. Much of the propaganda used in marketing materials often places the emphasis wrongly and may be misleading. The fertilizer manufacturer must discriminate. He courts and invites the cooperation and advice of the soil scientist in making an honest decision.

It is equally important that the findings of our scientists should be understood by the farmer, the user. This fact is well known to those who are engaged in the American fertilizer industry, which through its educational bureaus, with its corps of soil scientists, translates into Farmer's English the language of our scientific experts. The new methods that are now in the offing can be applied successfully only by scientifically sympathetic executives and technically trained operators.

How can the student of the soil hitch his science more directly to the plow? How can he gain the more general cooperation of the farmer in his work? To say that doctors disagree is to make a commonplace remark. To say that they agree might be a bit of news. Is it practical for the soil men of the world, acting as a committee of the whole, to agree to recommend certain sound practices in the treatment of soil of various types, in drainage, in earth sanitation, seed selection, tillage, means of forcing maturity in such simple form that agricultural teachers and farmers could make full use of it in a practical way? As we come in contact with farmers we sense a need for some such agreement, a lack of which increases their inertia.

The keynote, then, of my thesis is that, in this period of transition of world agricultural practice from extensive to more intensive methods, when, in order to be economical, production must become more intensive, both the farmer and the fertilizer producer look to you for scientific and educational leadership and instruction.

SPECIAL SESSIONS OF COMMISSIONS

2:00 P.M.—The afternoon, until a late hour, was devoted to holding meetings of the several commissions. A detailed account of each appears in the report of the Secretaries of the Washington meetings of the Congress.

RECEPTION

8:00 P.M.—The Honorable W. M. Jardine, Secretary of Agriculture, held a formal reception at the Pan American Union for delegates and members of the Society.

GENERAL SESSIONS—ADDRESSES

Third Day—Wednesday, June 15, 1927

9:30 A.M.—Before the principal addresses of the open meeting were presented the Congress paused to adopt a resolution, presented by Sir John Russell, expressing regret that Dr. Milton Whitney, Honorary Chairman of the American Organizing Committee, was too ill to attend the meetings. Following this resolution Dr. A. F. Woods, Director of Research, United States Department of Agriculture, spoke upon the Origin and Objects of the Bureau of Soils, in which Dr. Whitney, as Chief, had taken such a prominent part.

THE BUREAU OF SOILS—ITS ORIGIN AND OBJECTS

Dr. A. F. Woods

Members and Guests of the First International Congress of Soil Science:

The Bureau of Soils as an independent service bureau of the United States Department of Agriculture will be twenty-six years old on the first of the coming July. Like other agricultural bureaus of the Government it came into existence through the natural growth and development of the Department. The events in the evolution of the Department and of the Bureau of Soils may be reviewed with advantage.

That this country should take a national interest in its soils was in the mind of the country's first President, George Washington, when he wrote in his last message to Congress in 1796: "In proportion as nations advance in population . . . the cultivation of the soil becomes more and more an object of public patronage." Two events seem to have prompted Washington to give this expression to his views, one the establishment of the British Board of Agriculture in 1793 and the other his experience with exhausted soils on his plantation at Mount Vernon.

We must remember that Washington had a scientific type of mind, one which would naturally lead him to the observation and investigation of such vital elements of science as soils and their productive properties. Records show that as a man "first in peace" he was also first not only in social qualities, in engineering, in business affairs, and in diplomacy, but also in public welfare in the interest of both city dwellers and farmers, and consequently in soil improvement.

The suggestions regarding Governmental aid to agriculture made in his message to Congress were favorably received, but attempts to establish legislative aid failed. However, in 1839 the Commissioner of Patents, Henry L. Ellsworth, succeeded in getting a congressional appropriation of one thousand dollars to be used in collecting and distributing seeds, for agricultural investigations, and for gathering agricultural statistics.

In 1849 the Department of the Interior was established, and the Patent Office, with the agricultural branch, became a part of it.

The next important step toward organized agricultural development was taken in 1852, when the United States Agricultural Society, having for its object the improvement of the agriculture of the country, was formed. This national Society, which was created by a congress of farmers and was composed of delegates from the several State Societies, was particularly active in urging the establishment of a United States Department of Agriculture. The Society met annually in Washington until 1860, after which it discontinued, President Lincoln in 1862 approving a law providing for the organization of an independent Department of Agriculture—a law which made practical realization of the hopes of Washington. It is worthy of note that in the same year, 1862, the act was passed providing for the establishment of agricultural colleges.

In each of his annual reports for the three years after the Department was established Isaac Newton, first Commissioner of Agriculture, stressed the importance of weather and climate in connection with agriculture and suggested that information in regard to the weather be distributed over the country under supervision of the Government. His suggestions resulted in the organization, first, of a meteorological division in the Office of the Chief Signal Officer of the Army in 1872, and finally the organization of the Weather Bureau as a part of the Department of Agriculture in 1891.

Strange as it may seem it is nevertheless true that the Weather Bureau proved to be the mother of the Bureau of Soils. Because of the demand for information regarding the relation of soils to meteorological conditions the Division of Agricultural Soils was organized in 1894 as a part of the Weather Bureau and became an independent division of the Department of Agriculture in 1895, with Milton Whitney, who had been in charge of the Division since its organization, as Chief of the new independent Division. Twenty-six years ago, or on July 1, 1901, this Division was designated as the Bureau of Soils.

Work of the Bureau

The first duty of the Division was to study the rainfall and temperature in relation to soils, "and to keep a continuous record of the moisture and temperature conditions within some of the most important types of soil in the country," such as truck-crop lands, soils suitable for raising the several grades of tobacco, the different varieties of cotton and fruit, wheat and corn lands, and the soils of the arid and semiarid regions.

With a view to setting forth in a concrete way the objects of the Bureau and the position which it has won in promoting science and the agricultural interests of the country, I shall mention briefly some of its more noteworthy achievements:

(1) It instituted the Soil Survey and originated and developed the scheme of soil classification now in use; (2) classified and surveyed soils in all parts of the country, aggregating more than 1,280,000 square miles, or an area equivalent to about 43 per cent of continental United States; (3) developed methods for studying and grading alkali lands, and demonstrated a successful method for reclaiming arable lands made worthless by alkali accumulations; (4) demonstrated the feasibility of producing in this country the highest grade of Sumatra tobacco, with the result that a new agricultural industry has been established in the Connecticut Valley; (5) devised a method of mechanical analysis of soils, making it possible to group them into classes according to texture; (6) developed the dynamic concept of soils as opposed to the old static concept; (7) pointed out in a general way the relation of kind of soil to crop adaptation and production; (8) developed new sources of potash and showed that from 70,000 to 100,000 tons of potash annually lost through the flues of cement plants can be recovered and used in agriculture for fertilizer and also in other industries; (9) demonstrated the feasibility of manufacturing phosphoric acid for fertilizers by volatilizing phosphorus from either high-grade or run-of-mine phosphate rock; (10) investigated and showed the nature of soil organic matter, including organic compounds; and (11) developed methods for studying soil solutions and colloids.

The present activities of the Bureau include principally soil classification and mapping, nitrogen-fixation, fertilizer resources, and chemical and physical investigation of soils and soil conservation, especially the prevention of losses from erosion.

Our soil experts find that here as in other parts of the world failure to hold the absorptive surface soil of fields and pastures against the denudation of erosion has contributed to a much more rapid removal of the water that falls upon these eroded lands. The mellow topsoil that is gone was far more retentive of moisture than the comparatively impervious subsoil that sheet erosion has left behind. These experts believe that this wastage of the soil has as much to do with the constantly increasing floods as all other factors combined. Many streams navigable a generation ago are now clogged with soil débris.

Failure to build terraces on sloping fields generally and to plant grass and trees on the steeper lands highly susceptible to rainwash accounts for much of the excess of water now sweeping down the Mississippi. If this kind of soil wastage on an enormous scale is not stopped there is little likelihood that floods will be controlled. Practically nothing is being done about this phase of flood prevention. There are no hillside terraces north of the Arkansas River. Eighteen inches of topsoil has been removed from the youthful fields in some parts of northeastern Kansas. The entire topsoil is gone from hundreds of thousands of acres in western Virginia, western Pennsylvania, eastern Kentucky, and southeastern Ohio. From

these lands rain water courses much faster to the Mississippi than formerly. Terraces and grass wood lots, forests, and soil-binding and soil-building crops will vastly improve the flood situation. Not only will they slow up the run-off of water, but they will save the most valuable part of the soil, and will reduce the clogging of streams, which cuts down their carrying capacity and adds to the flood danger.

This problem of controlling erosion, both the slow and the rapid types is, I believe, the most vital soil problem we have and on which we are doing the least work.

The Soil Survey, under the leadership of Doctor Marbut, is gathering facts about soils and is endeavoring to discover the relationships of the soils of the entire United States. The fundamental work of the Soil Survey makes possible the building of a soil science, it makes possible a rational interpretation of soil experiments, and it points a way to the discovery of the principles on which soil management should be based.

As the population of the world increases the Nations must give more and more attention to ways and means of increasing the production of food. Fertilizer resources have already become national problems. In the United States the problem of fertilizer resources is studied in the Bureau of Soils. Research along this line deals with the fixation of atmospheric nitrogen as synthetic ammonia, the utilization of fixed-nitrogen products for fertilizer purposes, the problem of concentrated fertilizers, the economic utilization and conservation of our natural phosphate deposits, the investigation of our greensand deposits as a possible source of potash, and the utilization of organic waste as a source of organic nitrogen.

Research in soil chemistry is confined principally to studies of soil colloids and the chemical nature of the materials of which soils are composed. Much of this chemical work, therefore, is done in connection with the work of the Soil Survey. The work on soil colloids has given much valuable information regarding the nature of soils and of soil materials for use in the construction of highways.

Though much of the early work in soil investigations dealt with the physical properties of soils, no method of mechanical analysis has yet been developed which will enable the soil scientists of different countries of the world to agree in their interpretation of mechanical analyses. The Bureau has done much pioneer work on mechanical analysis, and some of its recent work has been done in an effort to devise or choose a method of analysis that will make possible a universal scientific interpretation of the physical properties of soils, and to make it possible to compare the dominant soils of one country with those of another in their physical composition. This one fact may serve to illustrate the influence that soil science has in instigating constructive soil investigational work.

According to approved plans, the Bureau of Soils will soon be a part of a new and larger bureau, under the title of the Bureau of Chemistry and

Soils. In this new bureau will be centralized all the investigational work in soil classification, physics, chemistry, soil biology, fertilizers, soil fertility, and soil technology. The new bureau, therefore, will be fully equipped to render a greater and more useful service to agriculture, thus bringing into practical realization what was in the mind of those agricultural leaders who have gone before, namely, the kind of governmental aid that will make agriculture a strong bulwark of the Nation.

STATUS OF SOIL BIOLOGY

Dr. E. J. Russell, England, reviewed Soil Microbiology and discussed its bearing upon agricultural practice.

THE PRESENT STATUS OF SOIL MICROBIOLOGY

DR. E. J. RUSSELL

INTRODUCTION

The special province of soil microbiology is the study of the relationships between the organisms of the soil and the higher plants growing on the surface. Broadly speaking the underlying relationship is that the higher plants furnish the source of energy for the soil organisms and the organisms furnish important nutrients for the plants.

The setting up of soil microbiology as a separate study is a matter rather of convenience than of fundamental distinction. The microorganisms living in the soil are subject to the same general biological laws as microorganisms living anywhere else. But the conditions in the soil are sufficiently unlike those in other habitats to give certain distinctive characteristics to the flora and fauna, while they are sufficiently alike over large parts of the world to impose a basis of uniformity such as is necessary before any set of natural phenomena can be studied as a separate subject.

The chief unifying conditions common to all soils are:

(1) The nature of the medium on which the organisms live, which in the main is a colloidal jelly formed of organic and inorganic substances coating the soil particles; usually it is more or less saturated with water and surrounded by an atmosphere containing little less oxygen than the air we breathe.

(2) The source of energy; this for nearly all organisms is the plant material either alive or dead, or a product derived therefrom; of the rest only the algae living on the surface of the soil can directly utilize the sun's rays, those in the interior of the soil feeding upon organic matter, as M. Bristol-Roach has shown, while the amoebae and ciliates, which do not themselves obtain their energy from the plant, feed upon organisms that have done so.

The microorganisms found in the soil are mainly algae, bacteria, fungi, including the remarkable mycorrhiza studied by M. C. Rayner and J. E. Magrou, actinomycetes, nematodes, protozoa and certain other invertebrates such as the *Enchytraedeae;* there are also a few myxomycetes. Certain species of each of these groups occur so commonly in a trophic state in the soil that they can be regarded collectively as a soil flora or fauna. The whole of these groups make up the soil population.

So far as is known, the composition of the soil population shows remarkably little variation in different parts of the world. The characteristic groups of algae, fungi, bacteria and protozoa are apparently the same in the Arctic as in temperate and tropical climates; there seems to be nothing corresponding to the geographical distribution of plants and animals. How far the similarity extends is not known; our methods of examination are somewhat crude and may easily miss important differences; but some degree of uniformity results from the fact that the biological conditions at a depth of 2 to 7 or 8 inches below the soil surface vary much less than on the surface itself.

While the general groups remain the same, their relative numbers vary from place to place, making new combinations recalling the ecological associations of higher plants, while some forms are altogether absent in certain conditions.

For the soil flora perhaps the most potent single factor determining exclusion is the reaction of the soil. The relationship between the pH values and the degree of prevalence of certain organisms is very close. Azotobacter are particularly sensitive to acid conditions; indeed Christensen has worked out the details of an Azotobacter test for soil acidity. The various strains of *B. Radicicola* are also very susceptible; in Denmark the probable need of inoculation of leguminous crops is inferred from the acidity of the soil and inoculation is not made till the acidity has been corrected.

As the acidity becomes pronounced bacteria tend to diminish in numbers; the fungi, so far as is known, do not, so that the flora tends to become more markedly fungal.

The protozoa appear to be less susceptible to variations in soil reaction though the relationship between their numbers and the pH values of the soils is not known; nor is it known how the microscopic animals are affected. Larger animals, e.g. earthworms and snails, are somewhat intolerant to acid soils, possibly because of their need for calcium.

Another important fact leading to modifications in the soil population is the air supply.

Certain floristic and faunistic differences have been recorded which, however, are not yet explained. Hagem claimed to find different species of *Mucor* in different types of soil suggesting ecological communities of fungi although according to later results the difference is probably one

of balance rather than absolute exclusion of particular species. Cutler, Crump and Sandon in their numerous examinations of the protozoan fauna of soils rarely found *Dimastigamoebae gruberi* and *Hartmanella hyalina* occurring together; apparently there is some mutual exclusiveness. Certain groups of *Bac. Radicicola* occur only where their host plants grow. Gray and Thornton find that one group of the phenol decomposing organisms (*Mycobacterium agreste*) tends ot occur more frequently in the drier parts of England than in the wetter. Whether similar variations would be found in other groups if they were studied in equal detail is not known.

For physical reasons direct microscopical examination of the soil itself is very difficult and apt to be entirely misleading. The staining methods of Conn and of Winogradsky promise to open a way of overcoming the difficulty. Hitherto cultural methods only have been possible and these suffer from the defect that they do not show at what stage in its life cycle any particular organism may be, nor even whether it is in a tropic or inactive state.

Considerable knowledge has, however, been given by the methods which have been elaborated for estimating the numbers of each of the various organisms in a given weight of soil. When used on field soils these have brought out three important characteristics:

(1) The level of numbers of all groups of organisms depends on the amount of energy material, i.e., of plant residues, available provided nothing is operating to keep the numbers down.

(2) Increases in the energy supply in absence of any limiting factor cause increase in the numbers of organisms. If the energy material is a pure substance the organisms increasing may be of one group only as shown by Winogradsky. But if the energy material consists of the complex mixture that forms plant residues many groups of organisms increase. In adjacent soils those richer in plant residues contain not only more individual organisms but also more kinds of organisms. It is not known whether this results from new infections or from the multiplication up to measurable quantities of organisms previously too few to count.

(3) In any one soil the numbers of bacteria and protozoa (it is not known whether this applies to other organisms also) do not remain constant even under approximately constant conditions, but fluctuate continuously. The fluctuations in bacterial numbers are in the opposite direction to those of the active amoebae and are apparently caused by them. It is not clear, however, why the amoebae should fluctuate. No relationship can be traced between the fluctuations and the moisture content of the soil, the rainfall or the temperature. In at least two cases a periodicity of numbers has been observed which seems to be a specific property of the organism itself associated probably with reproduction changes. Cutler and his colleagues have shown that the flagellate *Oicomonas termo* fluctu-

ates regularly in numbers from day to day in normal field conditions, while Thornton and Gangulee found that *Bac. Radicicola* fluctuated in numbers when it was the only organism present in a sterilized soil; whether or not the fluctuations occur in normal soil the method was not suited to determine. The fluctuations of *Bac. Radicicola* were traced to the different modes of reproduction at different stages of the life cycle. Whether other organisms fluctuate in numbers from this cause is not known, though it seems probable.

The absence of simple relationships between fluctuations in numbers and external physical conditions does not rule out the possibility of their existence.

In a mixed population of organisms, some of which are directly interacting and all are indirectly affecting each other by the circumstance that their total amount of activity is fixed by the energy supply, which changes only slowly, it needs only a few groups of fluctuating organisms and some selective action of external conditions on rates of multiplication and of death, to set the whole lot fluctuating.

Superimposed on these daily fluctuations are the great seasonal changes; all groups for which counts can be made tend to greater numbers in spring and autumn and lower numbers in winter and summer. The cause of this is not clear but bacteria and protozoa alike are affected; the inverse relationship shown by the daily numbers does not hold for the seasonal mean values.

The results of the activity of the microorganic population are included in the total amount of chemical change in the soil but there is no means of distinguishing between the parts brought about respectively by microorganisms and by simple chemical reactions. In general the distinction is not attempted and the whole of the chemical changes involving organic compounds are tacitly attributed to microorganisms.

These changes consist in the conversion of the complex organic substances of the growing plant into the end products, carbon dioxide, water, nitrates and ash constituents. The intermediate products are of several kinds; sticky colloidal substances collectively called "humus," and crystalloid substances such as are obtained in the hydrolysis of protein in the laboratory and suggesting that a similar decomposition of protein occurs in the soil.

The transformation of the plant residues into humus has been much studied because of the important physical changes involved; the original residues tend to open up the soil and facilitate loss of water by evaporation; the colloidal humus by its great power of absorption prevents loss of water though equally favorable to aeration. For long it was supposed that all the plant constituents tended to form humus; it is now known that only the cellulose and lignin contribute to any important extent and chemists are tending more and more to regard these as the parent sub-

stances. Waksman has shown that part of the fungal mycelium is soluble in alkali and precipitated by acids and would therefore appear in the humus fraction.

Of equal importance with this conversion of structure material into colloid material are the changes in total nitrogen and in nitrate content which, however, are too well known to need description.

Another type of reaction of great importance so far as it occurs is the decomposition of intermediate products which if they persisted in the soil would be harmful to the plant: such for example as the phenolic substances formed in the decomposition of protein, and the hydroxystearic acid discovered by Schreiner and Shorey: other toxic intermediate products seem to occur also. So long as these substances persist in the soil they are harmful to plant growth; fortunately they are readily decomposed by microorganisms.

The simpler of these reactions can be studied quantitatively and the rates of accumulation of the products measured. If the reactions were brought about wholly by microorganisms these rates could be used as measures of the activity of the population. The fact that purely chemical changes occur preclude such simple values as absolute measurements of biological activity; nevertheless they have considerable value for comparative purposes.

The simplest reactions to measure are the absorption of oxygen and the evolution of carbon dioxide. The oxygen absorption was studied by the writer, the evolution of carbon dioxide by a number of investigators from Wollny to Stoklasa and the Scandinavian investigators L. G. Romell and H. Lundergardh. It appears from these measurements that a field soil devoid of growing plants may evolve from 4 to 50 g. CO_2 per sq. metre per day during the summer period corresponding to an absorption of 2 to 26 l. of oxygen. Another mode of expression is to estimate the energy change: to determine the heat of combustion of the soil at the beginning of the season and again at the end, making allowance for any organic matter that may have been added. On the Broadbalk soils it appears that from 1 to 15 millions kilocalories of energy are dissipated per acre per annum according as the land is left without manure or given farmyard manure annually. These values are of interest in soil microbiology but have not yet proved helpful in solving agricultural problems.

More useful data from the point of view of crop production are obtained by studying the changes in the nitrogen compounds, particularly the total nitrogen in the soil and the amount of nitrate. Here the part played by microorganisms can be more definitely determined since so far as is known only a few can fix nitrogen and change ammonia to nitrate in the soil. The production of ammonia, though chemically simple, is biologically much more complex since it can be effected by a large number of

organisms and by chemical processes independent of microorganisms altogether.

So far as the measurements have been made—unfortunately they are only few—they show seasonal fluctuations in the amount of nitrate in the soil corresponding to those of bacterial numbers but nothing corresponding with the daily fluctuations. This is not difficult to understand; activity and numbers are not necessarily closely related and the numbers of all organisms do not fluctuate in the same way; the curve for total activity of the population may therefore be smoother than that for the numbers of any particular organism.

The older conception of the soil population was that its component members each had special functions so that it could be divided into groups of nitrifiers, ammonifiers, nitrogen fixers, denitrifiers, pectin fermenters, etc. It is now known that few of the reactions except nitrification and nitrogen fixation are sharply limited to one or two organisms; and that few organisms except perhaps the nitrifiers are sharply limited to one chemical change. The fundamental relation to decomposition is the search for energy and most of the organisms are able to effect a variety of changes in order to get it; in some circumstances one, in other circumstances another change may prove the simpler. Bonazzi gives some good illustrations. The most effective measures of the activity of the organisms would be the heat evolved from the soil by the natural decomposition and oxidation processes; unfortunately no method has been devised for overcoming the experimental difficulties.

This recognition that the search for energy is, so to speak, the driving force in the changes effected by the soil population, has greatly increased the difficulty of ascertaining the part played by any particular group of organisms. The old argument that because an organism can effect a particular change in artificial culture it therefore effects the same changes in the soil is now recognized as fallacious. The statistical method is to trace the rate of the reaction and the changes in the numbers of the various organisms, then to find which are related; this, however, is uncertain. The direct method of starting with a sterilized soil free from all microorganisms, and building up the soil population gradually, observing at each stage the changes produced, appears to be in principle the soundest. In practice it has hitherto been inapplicable owing to the great physical and chemical changes induced by sterilization. A method involving only drying *in vacuo* at laboratory temperatures has now been introduced by Dr. MacLennan which may overcome this difficulty and allow of a synthesis of the soil population; if this expectation be realized it will greatly advance soil microbiology.

Until some method has been devised for following up the activities of the different organisms in the soil we cannot expect to put soil microbiology on a sound basis. Useful information is steadily being accumu-

lated about the method of decomposition by various organisms, especially the relationships between the amount of decomposition effected and the amounts of carbon and of nitrogen assimilated by the organisms.

The history of agricultural science shows that advances have been made in two ways: by fundamental investigations in the laboratory and by attempts to find practical applications of knowledge gained or to solve practical problems in the field. Several applications of soil microbiology to agriculture have already been made and have not only proved of great agricultural value but have added to our fundamental knowledge and thus opened up the possibility of further advances.

Soil Microbiology and Soil Fertility

The relationship of soil microbiology to soil fertility is two fold: the organisms are the chief agents bringing about changes in the soil organic matter; and some of them exert a direct effect on the growing plant. A distinction is therefore made between the saprophytic and the parasitic organisms.

The changes in the soil organic matter are of two kinds. There is a building up of complex compounds, the necessary energy being derived either from the sun by algae living on the surface of the soil, or from the oxidation of other organic matter by organisms lacking the power of photosynthesis, including the algae themselves when they are living in the darkness of the soil. Both changes result in the formation of cell material; the second predominates, so that the net result is a loss of total organic matter. Far more important, however, is the change in the nature of the organic matter. The organisms in growing and producing cell material were compelled to assimilate nitrogen. Most of them take this in the form of nitrates or ammonia; a few can directly assimilate gaseous nitrogen; either action represents a gain of nitrogen; the former is a protective gain since the nitrate and ammonia are easily liable to loss; the latter is an absolute gain and was indeed probably the way in which soils obtained their original stock of nitrogen. The general result of this group of changes is therefore a loss of carbon as carbon dioxide and a much smaller loss or even a gain in nitrogen; the conversion of non-nitrogenous organic matter of little direct value in plant nutrition to cell tissue, nitrogenous organic matter which is of great potential value though its immediate availability seems to be small. Waksman has pointed out that fungi assimilate considerably more of the carbon on which they act than do bacteria and to this extent they are more economical transformers.

The second type of change is the decomposition of the organic matter. The obvious relation to fertility is that the original organic matter—mainly plant residues still retaining their structure—is of no direct use to the growing plant and indeed on light soils may have the indirect effect

of causing loss of water by evaporation; while the decomposition products are of great value. The colloidal "humus" exercises well-known beneficial effects and the simple end products—nitrates, ash constituents and carbon dioxide—are direct plant nutrients.

Both changes therefore contribute to the fertility of the soil: the first to its stores of potential fertility, the second to its actual fertility. An obvious practical application to agriculture would be to hasten these processes in the soil; the conservation processes in periods when no crop is growing, and the liquidation processes when there is a crop. Unfortunately for microbiology the same factors that contribute to the growth and activity of soil microorganisms also benefit the higher plants and the farmer is already carrying out all the microbiologist would have recommended.

In several other directions, however, applications to practical agriculture have been made.

The Fixation of Nitrogen in the Soil

The activity of the free living nitrogen fixing organisms can be stimulated by adding easily assimilable non-nitrogenous organic matter to the soil. This increases the energy supply and therefore the numbers of many of the groups of organisms; their need for nitrogen drives them to assimilate ammonia and nitrate from the soil. There is thus an immediate reduction in amount of nitrate in the soil which temporarily reduces its productiveness, but this is followed by an increase in the total amount of nitrogen resulting from the activities of the nitrogen fixing organisms. This method has not, however, proved economic in practice owing to the low price of nitrogenous fertilizers as compared with non-nitrogenous organic matter. Digestible carbohydrates such as sugar, starch, etc., are more profitable as food for animals than for microorganisms while cellulosic material is more usually converted into humus than oxidized for the purpose of fixing nitrogen. If the price of nitrogenous manures should rise the case might be different, but as things stand there seems no prospect of this method coming into intensive use.

In arid conditions the residues of non-leguminous crops seem to cause more nitrogen-fixation than in humid conditions and consequently the free living nitrogen fixing organisms assume greater importance.

In humid conditions the most important nitrogen-fixation is that effected by the symbiotic organisms [1] associated with the leguminosae. Their activity can be much increased, leading not only to enhanced soil fertility but to an increased yield of valuable fodder crops. The simplest

[1] Although the free living organisms can, as their description implies, work quite well in pure cultures, they become more effective when associated with other organisms. It does not seem to matter whether the others are algae, bacteria, other strains of Azotobacter or protozoa; an increased fixation follows the admixture with other forms.

method of accomplishing this is to make the soil conditions suitable for vigorous growth of the organisms and then to inoculate the desired strain into the soil.

Inoculation of Leguminous Crops

The possibility of inoculating cultures of the nodule organism into the soil was first studied by Hiltner, one of the great founders of soil microbiology. Sufficient success was obtained to show the feasibility of the method but the failures showed that all the conditions for success were not fully known. Gradually the difficulties have been overcome, particularly by C. Barthel in Sweden, H. Christensen in Denmark, F. C. Harrison in Canada, the Bureau of Plant Industry in the United States and H. G. Thornton in England. Inoculation is now a practicable process which has proved very useful in the growth of leguminous crops, particularly of lucerne.

Improvements in recent years have been in three directions: in the selection of the particular organism to be used: in the preparation and transmission of the culture from the laboratory to the farm; and in the method of use on the farm. In the making of the cultures C. Barthel's investigations have proved helpful in showing that a laboratory stock of organisms could be kept in a vigorous condition in sterilized soil thus obviating the need for frequent recurrence to the nodules themselves. Rigid selection of the organisms used for inoculation is necessary because there are a number of groups each of which is capable of infecting only a limited group of host plants. This specific effect is not restricted to their relation with plants but is shown in other ways also such as their reaction to serological tests. Within these groups there are strains which, though capable of infecting the same plants, differ in several important characters. J. W. Stevens and Wright have shown that the strains of the lucerne and soya bean organisms differ in their efficiency as nitrogen fixers and in the manner—or more probably the time—of their attack on the plant roots; some forming nodules on the tap root, others on the side roots only. Serological tests were found for distinguishing between them.

Improvements in the technique of inoculation have resulted from a fuller knowledge of the life cycle of the organism in the soil gained by Bewley and Hutchinson and by Thornton and Gangulee. The active "swarmer" stage during which infection probably occurs is preceded by an inert stage. Thornton and Gangulee showed that the setting in of the swarmer stage and therefore of infection is hastened by adding milk and phosphates to the culture.

Hiltner regarded the relationship between the organisms and the plant as a parasitism, a view with which later workers agree. Recently W. E. Brenchley and H. G. Thornton have shown that in the broad bean the proper linking up of the bacteria with the plant is dependent on the

presence of a trace of boron. In its absence there is little or no development of strands from the vascular system to the nodule; the bacteria, though in the root, are unable to draw sugar from the plant or to transmit to the plant the nitrogen compounds they have synthesized; instead they begin to attack the root tissues and cause injury. Most soils probably contain sufficient boron, but it would be interesting to enquire what would happen on soils if there are any, from which plants cannot draw an adequate supply.

Extended tests of inoculation for lucerne in England have shown that it is always beneficial and usually necessary on soils which have not previously carried the crop. The effect depends very much on the amount of available nitrogen present in the soil; if this is considerable the plant grows without the organism as fully as other conditions permit though of course it is obtaining its nitrogen from the soil and not from the activities of the organism. Inoculation may show no effect in the first year till after the first cut has been taken. On the other hand soils containing but little available nitrogen show an immediate response to inoculation. There is always an increase in the quantity of nitrogen contained in the crop per acre; this may be accompanied by a larger weight of crop or an increased percentage of nitrogen without increase in crop, or more commonly by an increase both in weight of crop and in percentage of nitrogen.

Soils which have previously carried lucerne (of which there are many in the southeastern part of England) do not always respond much to inoculation, there being commonly sufficient nodule formation from the "wild" bacteria already present. Inoculation may hasten the appearance of the nodules, because the wild bacteria may be some distance away from the rootlets, but this is of little advantage where there is sufficient nitrogenous plant food in the soil for the young plants. But if the land be weedy or a cover crop be sown the soil nitrogenous compounds may be used up, causing the lucerne to be dependent on its nodules at an earlier age; inoculation then is beneficial.

The instructions issued to British farmers with the cultures are set out below:

Keep the cultures in the dark until used; they keep 30 days. In the cultures the bacteria appear as a whitish slime on the inclined surface of the jelly medium.

To Inoculate

The seed should first be piled on a clean surface. Take 1 tube of culture in ¼ pint of fresh skim milk per 7 lb. seed and shake up 0.5 g. calcium phosphate [1] per pint in this. Transfer the contents of the tube by means of a clean stick to the skim milk and *thoroughly* mix the bacterial slime with the milk, picking out the lumps of jelly medium. Rinse the

[1] The proper quantity is supplied with each culture.

tubes out into the milk. Thoroughly mix the seed with the inoculated milk which should be added a little at a time until every seed is moistened. The seed should not be too wet. It usually takes about a pint of milk to every 30 lb. of seed.

Sowing

The seed should be sown as soon as possible after inoculation. If the seeds are too wet they should be allowed to dry in a shady place. Under no circumstances should the cultures or the inoculated seed be left exposed to the sunlight, as this destroys the bacteria. For this reason also the seed should be drilled, or if broadcast, should at once be harrowed in.

Control of the Soil Population

The soil population is highly complex but all of its members require nitrogen, phosphorus, potassium and other plant nutrients for their growth and therefore all of them compete with plants for the available supplies. Some of them, as a result of the decompositions they effect, produce more of these nutrients than they can consume; others, however, do not. It has long been known that partial sterilization of the soil increases its productiveness. The changes produced are complex, being partly chemical and partly physical, but apparently mainly biological. This is not the place to summarize the enormous body of investigations that have been made on the subject, but the net result is that the new conditions and the new population leave a greater balance of plant nutrients than the older one. In some soils this normal falling off from the maximum possible supply of nutrients is intensified by the presence of disease organisms or other factors unsuited to the plant, and such soils are said to be "sick." The condition is vague and investigation is difficult; some workers including Ruschmann and Korinek distinguish a "sickness" for germination and another for growth (Keimungsmüdigkeit and Wachstummüdigkeit). Whatever the cause, sterilization by heat or antiseptics provides a remedy.

Partial Sterilization of "Sick" and Other Soils

The practice of partially sterilizing soil by steam and antiseptics has been widely adopted among the growers of tomatoes and cucumbers in England as a result of the Rothamsted investigations. These crops are grown under glass and for convenience of business organization the industry is confined to certain districts, notably the Lea Valley northeast of London, where it has developed rapidly of recent years, considerable areas of pasture land having been covered with glass and converted into cucumber and tomato borders. It is the common experience that for the first few years of cultivation high yields are obtained under proper

management, the cucumbers giving up to 90 tons per acre and the tomatoes up to 50 tons or more. But after this initial flush of crops the yields drop and are not again raised to their previous level by manuring; sometimes they may fall to only about one-half and the soils are said to be "sick."

During these years of cultivation under new conditions considerable changes have gone on in the soil, the cumulative effect of which is to reduce its productiveness. There has been an oxidation of the fibrous roots which opened it up, ensuring adequate aeration and drainage and satisfactory tilth, all factors of great importance in glass house cultivation. Among the biological changes are the gradual accumulation of disease organisms and pests, especially eelworms (*Heterodera*) and certain destructive fungi, in addition to the rearrangement of the soil population, the new grouping being apparently less effective than the old in producing plant food. Probably other changes are involved; precise investigation is hampered by the difficulty of retaining adequate controls.

A satisfactory treatment of these soils is to heat them by steam, using the well-known "tray" method [1] or to treat them with carbolic acid at the rate of 2½ tons per acre. This has proved so satisfactory that "sick" soils are now rare in England; before this stage is reached they have been steamed or treated with carbolic acid. They can still be found, however; one studied in 1925 by the Lea Valley Research Station yielded only 28 tons of tomatoes per acre; a portion that was steamed, however, yielded 50 tons per acre, while a part treated with carbolic acid yielded 43 tons per acre. The practical problem has now shifted and sterilization is adopted rather as a preventive than as a cure.

Unfortunately steaming is costly and the carbolic acid, while cheaper, is rarely as effective. Search has therefore been made for more potent chemicals. A heavy oil produced as a by-product from the Mond Gas process was better, giving 6.25 lb. per plant when applied at only half the usual rate as against 5.5 lb. for the full carbolic treatment and 5.25 on the untreated soil; steam, however, raised the yield to 7 lb. per plant. This particular oil is not easy to apply and persists long in the soil. In another nursery it was less effective, the untreated plots yielding 4.8 lb., while the oil gave 5.4 lb. and the carbolic acid 4.3 lb. per plant.

Two organic substances, possible intermediates in the dye industry, have been studied: chlordinitrobenzene and 3.5 dinitro-o-cresol; the former was more effective than carbolic acid even when used in only one-seventh the amount (0.02 per cent the weight of the soil instead of 0.15 per cent), giving an additional 2 tons of tomatoes per acre, as against 1 ton given by carbolic acid. In these trials the soil was initially good, the yields on the control plots being 44 tons per acre beyond which it is difficult to go.

[1] For a description of the English practice see W. F. Bewley, Journal of the Ministry of Agriculture, 1926, 297–311.

Preparation of a Manure from Sewage and Other Effluents

It has long been a reproach to science that of the vast quantities of nitrogen, potassium and phosphorus consumed annually by Western European and Northern American peoples, only a very small part returns to the land, the rest being lost or dissipated at great expense. Careful food statistics of the United Kingdom compiled during the war showed that the population (which then was 45.2 millions and has since increased) consumed 1,438,000 metric tons per annum of protein containing 230,000 tons of nitrogen. Most of this is excreted and a considerable part appears in the sewage; on the average per head of population, 11 lb. of nitrogen is excreted annually, 86 per cent being in the urine and 14 per cent in the faeces. Data for potash and phosphates do not exist, but assuming that these were about one-quarter the value of the nitrogen figures the fertilizer value per annum of the excrements of the population of the United Kingdom would be:

	Nitrogen	P_2O_5	K_2O	Value per annum
Total, tons per annum	230,000	57,000	57,000	£17,590,000
Average, lb. per head per annum	11	2¾	2¾	7s. 9d.

This is approximately equal to the value of farmyard manure and all the other fertilizers put together. Owing to various losses, however, only a small part of this ever reaches the sewage works. An average quantity of domestic sewage is 33 gallons per head per day containing 5 parts of nitrogen per 100,000; this corresponds to 6 lb. nitrogen per head per annum. Further, only a portion of the population is connected with sewage systems. Unfortunately no practicable means of realizing the value of sewage has yet been devised. Broad irrigation and sewage farming answer under certain conditions, but not as general methods of treatment. The only material generally available is the sludge which is prepared by some precipitating or settling process, and therefore contains only the insoluble compounds and not the soluble and valuable nitrates, ammonia, etc. This indeed is its weakness; it has been so well washed during the process of formation that it has lost much of its decomposable material.

Various experiments have frequently been made to ascertain the manurial value of sludge, but the results have not been very satisfactory. The usual course of events is that farmers are first induced to purchase it but finally have to be paid to take it away. Methods have therefore been devised for improving the sludge, perhaps the commonest being to add a certain proportion of lime and then to force the mass into presses when it forms a cake containing roughly 50 per cent of water, 15 to 25 of organic matter and 25 to 35 per cent of mineral matter much of which is lime, and about 1 per cent each of nitrogen and P_2O_5. A number of these pressed

sludges have been tested from time to time, but the results are disappointing. Up to the present the only sludge of promise as a fertilizer (we express no opinion as to any other property) is the Activated Sludge made by blowing air through the sewage. This contains when dry some 6 per cent of nitrogen in an easily available form and is worth on the farm up to £5 per ton. Since ordinary sludges contain only 1 or 2 per cent it was at first thought that the richness of activated sludge was the result of some fixation of gaseous nitrogen, but experiments at Rothamsted showed that it came from a better recovery in the sludge of the nitrogen of the sewage, the proportion being 15 per cent or more (rising in favorable conditions to 27 per cent) as compared with 10 per cent by precipitation and 4 per cent by septic tank methods. Further work has shown that this higher efficiency of recovery is due to a greater absorption of ammonia from the sewage.

This absorption is largely due to microorganisms which assimilate the ammonia and convert it into protein and protoplasm. Algae, fungi, bacteria and protozoa all take part; the two latter are related, the bacteria assimilating the ammonia and the protozoa assimilating the bacteria; finally the protozoa are entangled in the sludge and when dead and dry contribute largely to its fertilizing value. The smooth working of the process depends on maintaining a proper balance between the numbers of protozoa and of bacteria. A remarkable instance of failure was traced by Cutler to the introduction of yeast material from a brewery with the effluent; this yeast had stimulated the development of the protozoa which in turn had reduced the bacterial population so much that they could not adequately purify the sewage. As soon as the discharge of yeast was stopped the normal purification was resumed.

An even more efficient absorption of the nitrogen from the sewage can be obtained by allowing the effluent to flow over straw or similar material which furnishes the bacteria with energy material, causing them to multiply rapidly and assimilate large quantities of nitrogen from the sewage.

These relationships between the nitrogenous and the non-nitrogenous constituents and between the bacteria and the protozoa furnish the key to some of the difficulties encountered in dealing with sewage and other effluents.

Composting of Sulfur with Organic Matter and with Phosphates

The investigation of the microbiological oxidation of sulfur by P. E. Brown and his colleagues in Iowa, by J. G. Lipman, Waksman and Joffe in New Jersey, by other United States workers, and by C. Guittoneau have suggested application in two directions:

(1) The conversion of insoluble mineral phosphate into a soluble phosphate more rapidly available for plant food. In so far as this is an alternative to the manufacture of superphosphate, the choice between the processes is determined by economic considerations. There is, however,

the possibility that the sulfur may exert a fungicidal action which would give an added value to the mixture. No critical tests have been made in Europe though the patent rights have been taken up by certain enterprising firms.

(2) The addition of sulfur to soil with a view to changing the reaction towards acidity. This change is desirable on soils used for potato growing but liable to the common potato scab (*Actinomyces scabies*) since slightly acid conditions are more tolerated by the potato than by the organism. On a Wiltshire farm scab was found abundantly at pH 7.40 to 7.65 but not at pH 6.1 to 6.7.

In spite of this anticipated benefit sulfur has not proved particularly effective in England whether used in the form of flowers of sulfur or as inoculated sulfur, though it is said to have acted better in the United States. Other methods of changing the soil reaction have not been tried since a more promising method of dealing with scab appears to be the use of green manure as studied by Millard.

Biochemical Decomposition of Cellulosic Material: Preparation of Synthetic Farmyard Manure

The decomposition of cellulose by microorganisms is dependent on an adequate supply of available nitrogen and phosphates. The amount of nitrogen normally present in straw is insufficient for rapid decomposition; some breaking down goes on, but only slowly. The insufficiency of combined nitrogen gives scope for the activities of the nitrogen-fixing organisms and in consequence some nitrogen is fixed, usually about 0.1 to 0.3, but sometimes as much as 0.5 per cent of the dry weight of the straw. The amounts thus fixed are, however, still insufficient for the needs of the organism causing decomposition and, even with the higher amount of nitrogen-fixation, decomposition is very slow. In 1921 Hutchinson and Richards showed that addition of soluble nitrogen compounds at the rate of 0.7 part of nitrogen for every 100 parts of straw, and if necessary a sufficient amount of phosphate, caused decomposition to proceed rapidly (other conditions being favorable) with formation of humus.

Rege's investigations indicate that decomposition is brought about mainly by fungi which are thermophylic: e.g. *Acremoniella sp.*, *Aspergillus sp.* and *Coprinus sp.*; the first of these is able to function at the surprisingly high temperature of 60° C. and the others at 50° C. The direct energy supply appears to be the pentosans; on the other hand the lignin is ineffective and indeed appears to be actually harmful. When it exceeds the pentosan in amount decomposition becomes very slow.

The reaction has been made the basis of a process for preparing a manure, closely resembling farmyard manure, from straw and other cellulosic materials, and many thousands of tons are now made annually in different parts of the world.

An analysis of the material is made to show the amounts of nitrogen, lignin and available pentosan present. A nitrogen compound such as ammonium carbonate, urea, etc., or ammonium sulfate and calcium carbonate, is then added to bring up the nitrogen to the optimum amount which has usually to be ascertained by direct laboratory experiment. If the ratio of available pentosan to lignin is 1 or more, decomposition goes on rapidly so long as the heap is kept sufficiently moist and so long as acids do not accumulate.

If, however, more lignin is present so that the ratio available pentosan: lignin falls below 1, the decomposition may still be very slow in spite of the addition of available nitrogen. Materials such as banana stems or hop vines take a long time for decomposition while others such as sawdust, rice husk, old bracken, cocoa nut shell cannot be decomposed. Some of Rege's results are given in Table 1.

TABLE 1.—Decomposition of cellulosic materials to form humus

	Furfuroids (as pentosans)	Cellulose	Lignin	$\frac{\text{Available pentosans}}{\text{lignin}}$	Rate of decomposition
Rice straw	24.8	45.9	10.3	1.54	Rapid
Oat straw	28.8	51.7	14.2	1.13	Rapid
Barley straw	28.4	49.4	16.2	1.06	Rapid
Wheat straw	31.3	52.1	14.6	1.04	Rapid
Rushes	27.9	51.3	17.7	0.86	Slow
Maize straw	25.8	45.0	20.3	0.75	Slow
White ash	22.3	53.4	28.4	0.43	Very Slow
Poplar	20.7	66.3	28.4	0.34	Very Slow
Pine	8.9	57.4	26.6	0.12	Nil

Richards has now shown how to adjust the ratio of pentosan to lignin empirically and to secure the formation of humus from such unlikely substances as string and cocoanut fibre (coir). The discovery is likely to prove of great value in tropical countries where humus manures are much needed but there is no straw available for making it.

Whether the humus arises from the cellulose, the lignin or the fungal substances is not clear, but possibly all are concerned. The bacterial decomposition of cellulose is usually fairly complete, going as far as carbon dioxide and water with some relatively simple fatty acids and little or no humus. No decomposition of lignin by microorganisms has yet been proved, but the chemical oxidation to humus has been studied in detail by Eller and others.

The soluble nitrogen added to hasten the decomposition is, up to the quantity stated above, all converted into insoluble compounds, being no doubt assimilated by the organisms and built up into protein. Nitrogen

in excess of this amount is unnecessary and is liable to be washed out, lost by volatilization as ammonia, or dissipated as gaseous nitrogen. This commonly happens with young or immature plants; the decomposition of these therefore is liable to be wasteful of nitrogen. This relationship is important in green manuring in determining the stage at which growing crops should be ploughed under in order to give the maximum amount of humus and protein.

Microbiological Analysis of the Soil

Biologists, chemists and physicists have all alike striven to find single values which would readily express the respective fertility of members of a series of soils. With the recognition of the complex nature of soil fertility it is not supposed that any one value could have more than an approximate significance, but if such a value could be found it would be of considerable convenience to investigators.

All three groups of workers have in point of fact evolved some kind of single values and in so far as these have come into use their limitations are known so that they are not likely to be misleading.

But on the other hand the single values of one group of workers are not usually adopted by other workers. Those of the soil microbiologist may help him, but they probably will not be used by chemists or physicists.

The following single values introduced and developed by Remy, J. G. Lipman, Löhnis and others have been studied by microbiologists:

Rate of oxidation
Numbers of bacteria per gram
Ammonifying power
Nitrifying power
Cellulose fermenting power
Nitrogen-fixing power

None of these is universally applicable, but most of them show some relation to crop producing power, and, in the hands of a cautious worker, can be made to afford some index to fertility. This is especially true of processes such as nitrification, nitrogen-fixation and cellulose decomposition which are not general properties of many microorganisms but are restricted to a few species. In accordance with this expectation Waksman found in his critical studies of the methods that the ammonifying power is the least useful of any. The nitrogen-fixing power in a modified form has been used by Christensen in Denmark for estimating the need of lime and phosphates. Burri, Cochhead and Stoklasa have all made important contributions to the subject.

GEOLOGY IN SOIL SCIENCE

The rôle of geology in soil science was to have been discussed by Dr. G. De Angelis d'Ossat, of Italy, but Dr. d'Ossat was unable to be present at the Congress.

STATUS OF SOIL INVESTIGATIONS

Dr. A. Itano, Japan, presented an address in which the present status of soil investigations in Japan was reviewed.

PRESENT STATUS OF SOIL INVESTIGATIONS IN JAPAN

Dr. A. Itano

Introduction

A survey of the agricultural investigation in Japan indicates that many investigators are engaged on the problems of fertilizers but only a few in what may be called pure soil science.

I think this is the result of a great demand on the part of the farmers and agronomists, together with the economic condition in Japan. The Japanese farmers have been practicing very intensive farming in the past and have been getting fairly large yields per acre. They have, however, been obtaining much larger yields since the scientific agricultural information became available for their disposal. In fact, a marked increase of crop per acre has been realized in the past thirty years, which is chiefly due to the intelligent use of fertilizers, soil improvement, etc. On the other hand, the scientific knowledge concerning the soil itself has not been developed to any extent. It is not only true in Japan but all over the world. By this I do not mean to deny whatever we know already about the soil, but we should know a great deal more. I am sure that such a congress as this contributes greatly toward this end and I am eager to learn as much as possible during this Congress.

Japan faces a peculiar problem since the rice fields occupy a large portion of the cultivated soil which is volcanic in origin, as will be discussed later. When you consider that Japan is 680,762 square kilometers, of which about only 20 per cent is arable, and has 70,000,000 people with several thousand years of history, you realize how difficult it is to feed the population and also what might be anticipated from the agricultural scientists.

Land Forms of Japan

It is well-known that the Japanese Empire is made up of many islands. All these islands are the great circum-Pacific fold which was formed during the Tertiary period. The high mountain chains were formed as the result

of the enormous crustal disturbance. Some mountain peaks reach as high as 3,000 meters or more, and Mount Fuji, which is well known to you all, is a typical one. Besides the folding, blocking movements have been very frequent since the younger Tertiary period and extensive tracts of land of this origin are found in Japan, side by side with mountains caused by folding.

Through the various geologic ages, volcanic eruptions have occurred repeatedly and more frequently since the Tertiary period. Many cones found on the mountains and fields or rising from the sea are largely the heaps of lavas or ashes. Even today we have volcanic eruptions and earthquakes of various degrees of intensity, and recently we experienced some strong earthquakes, as you all know.

Besides these structural disturbances, the sculptural deformation of the land in Japan is very remarkable, and influences the soil conditions very greatly. The intense erósion is taking place by rain and snow which is the result of precipitation of immense amounts of vapor coming from the surrounding seas in summer and winter. Many short streams are found all over Japan, washing away ravines and valleys, thus making the topography very complicated and the gradient very steep.

The plains are found occasionally along the seacoast as well as along the banks of large rivers. The delta districts are generally well developed and fertile, as may be judged from the foregoing description.

Geographic Location and Climate

The Japanese Islands extend through about 30 degrees of latitude, or, in other words, from the tropic to the frigid zone; the climate varies considerably. However, an oceanic climate prevails everywhere in the country and the precipitation is generally very plentiful, so that a very agreeable temperate climate, which is an important factor for maintenance of general life, is found everywhere.

Farm Crops in Japan

In recent years rice, beans, mulberry leaves, tobacco, and tea are considered the most important and profitable crops in Japan, among which rice has been the most important one since it is the main diet of the Japanese.

Facilities for Investigation

The greater portion of the scientific investigations in Japan have been carried out in experimental institutes and especially in those under the control of the Imperial Government, although in recent years some private scientific institutes have been founded in Japan. The Ohara Institute for Agricultural Research, with which I am connected, was founded by Mr. Ohara fourteen years ago.

The Imperial Agricultural Experiment Station and the Station in each prefecture in the Imperial Universities, are well equipped, and directed by the men who were educated in Europe and America, offer very good facilities for investigations.

General Subjects for Soil Investigation

Judging from the previous discussion, one may project as to the nature of soil investigation in Japan.

For example, some of the important investigations which have been undertaken at the Imperial Agricultural Experiment Station are as follows:

1. On the change in soil constituents caused by the repeated cropping of rice.
2. Studies on certain organic compounds occurring in special types of soil.
3. Studies on acid soils; their origin, properties, and distribution, and the method of their improvement.
4. Studies on volcanic ashes and soil.
5. Studies on certain mineral constituents of soil.

As these projects indicate, the investigations are chiefly chemical in their nature. The physical as well as the biological aspects of the soil began to receive our attention only during the last few years. The adsorption by the soil particles and the influence of heat on the soil are investigated by some workers.

In connection with the biological investigation there are only a few investigators. Some of the results obtained at Professor Aso's laboratory and mine I have the pleasure of presenting at this Congress. In general, it may be stated that the general microbial analysis, the *Azotobactor* group, the Protozoa, and the cellulose decomposing organisms have been investigated.

Summary

In my presentation, I have tried to give a brief description of Japan as to her general conditions, a geological and geographical sketch, important crops, facilities for the soil investigations, and general subjects under investigation. I sincerely hope that I have conveyed some information to you as to the present status of soil investigation in Japan. I am sure that you found Japan at the initial stage on the soil investigation, especially as to the recent development, namely, physical and biological aspects of the subject.

I am very sorry that my original plan to illustrate this address failed because I could not have the slides made in time from the materials which I brought over with me.

The greater part of the ladies program for the morning was devoted to a sight-seeing trip during which the beauties of the Congressional library were viewed and the functions of the National Congress at the Capitol were witnessed, under the guidance of Mrs. Charles Brand.

SPECIAL SESSIONS OF COMMISSIONS

2:00 P.M.—A detailed account of the afternoon Proceedings are given in the Secretaries reports of the respective commissions.

8:00 P.M.—The evening was devoted to a formal dinner for the entire membership, held at the New Willard Hotel.

WESTERN MARYLAND EXCURSION

Fourth Day—Thursday, June 16, 1927

7:30 A.M.—At this early hour many of the delegates assembled at the Willard Hotel to participate in the excursion planned for the day.

TRIP THROUGH WESTERN MARYLAND

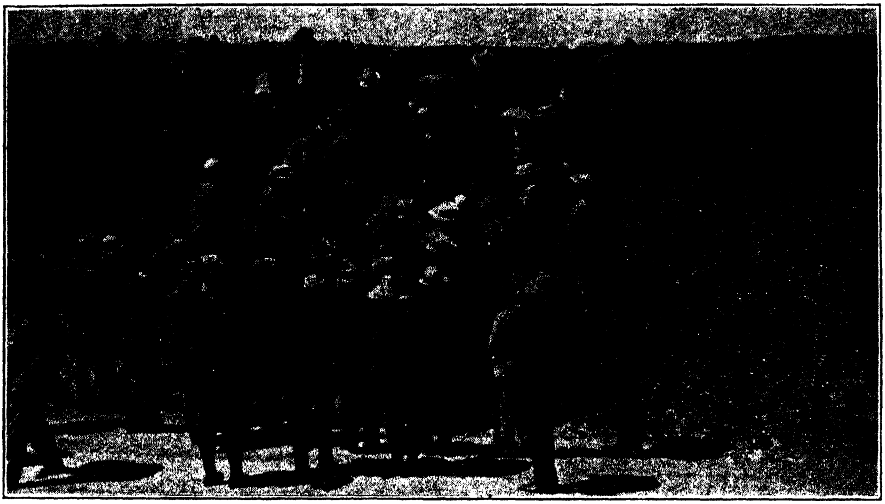
Ernest H. Bailey

At about 8:00 o'clock in the morning of June 16, three hundred and twenty of us left the Willard Hotel in twelve motor busses. A repair car followed the caravan and before the day was over it came in very handy. Accompanying us, were two guides mounted on motorcycles, whom some of our foreign friends mistook for police, to protect us from bandits. It was a beautiful June morning and everyone appeared in the best of spirits. We took the Frederick Pike which passed through the villages of Rockville, Gaithersburg, Damascus and Ridgeville and thence to the city of Frederick.

The country for the most part, until about two miles north of Gaithersburg, was gently rolling and well drained. The soil, as revealed by the roadcuts and the fields, had a reddish-brown color. This soil is called Chester loam. It is one of the most important soils in the Northern Piedmont, and is derived from the weathering of granites, gneisses and schists. About four miles north of Rockville, we stopped to examine a virgin profile of this soil in a roadside cut. The native vegetation consisted mostly of red oak, white oak, poplar and hickory. The upper inch of the profile was made up of a thin layer of leaf litter and dark brown soil, the dark color being due to the inclusion of organic matter. This constituted the A_1-horizon. The A_2-horizon consisted of about 8 inches of a dull, reddish-brown, friable loam containing a very small amount of fine scales of mica. The B-horizon was about 15 inches thick and was of a bright, reddish-brown color. This horizon, considerably more compact

and higher in colloids than the A-horizon, graded gradually into the looser C-horizon which was reddish-yellow in color and became more micaceous with depth. At about 4½ feet the structure of the underlying gneiss was noticeable in the disintegrated material although oxidation continued to a greater depth. The appearance of the native vegetation, crops and farm buildings indicated that this was a fairly good soil. A great deal of the land was in grass and pasture.

About two miles north of the village of Gaithersburg we crossed Seneca Creek. From there the topography became very hilly. Because of the

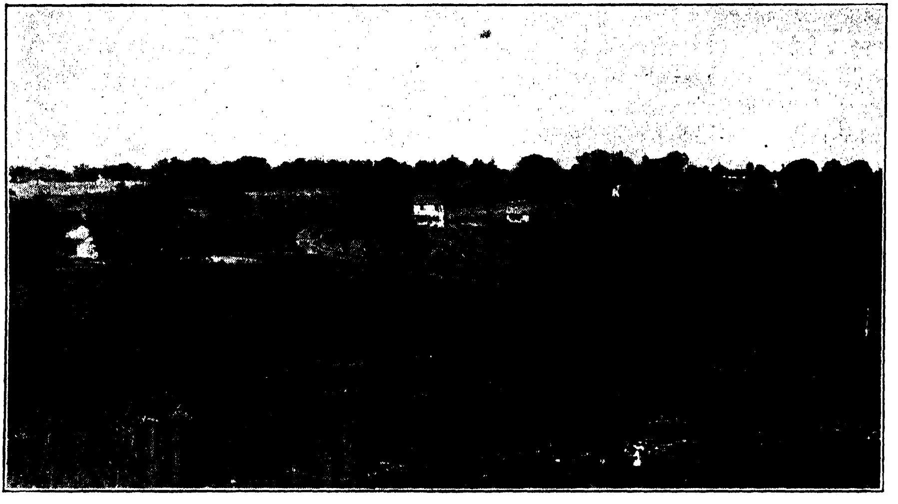


EXAMINING MARION LOAM SOIL PROFILE

very rolling nature of the country, the normal profile of the region had not developed. The Marion soils occupy this topography. Near Ridgeville we stopped and examined a roadside cut of this soil. An A-horizon of about 3 inches of a grayish-brown, highly micaceous loam had developed but no B-horizon had been formed. The C-horizon resembled that of the Chester, except for having a very much higher content of mica. The soil, throughout the profile, because of the large amount of mica present, had a greasy feel. This was a badly eroded soil. It differed from the Chester loam, both in the more rolling nature of its topography and in the higher percentage of mica in the parent rock.

About three miles east of Frederick we crossed the Monocacy River. Just west of it the yellow brown soil, derived from limestones and calcareous shales, occurred, being mapped as Frankstown silt loam. It occupied most of the Frederick Valley and appeared to be a very fertile and productive soil judging from the character of the vegetation, the crops, and the farm buildings.

The Buckingham School for homeless boys is situated a few miles beyond Frederick. We visited this school and learned that it was founded, by a wealthy man by the name of Baker, many years ago. His grandson, a business man from Baltimore, who is also named Baker, now maintains it. About sixty boys were in the school when we visited it. They have a fine, well equipped farm. The school cares for homeless boys under eighteen years of age. There they are supported, receive a common school education and are taught trades. They are helped to secure employment and become self-supporting. One of the busses broke down at this time and its occupants had to be distributed among the other cars. The repair car then came into play.



LANDSCAPE OF CHESTER LOAM SOIL TYPE

About two and a half miles west of Frederick, at the village of Braddock, we started the ascent of Catoctin Mountain where the soils were very thin and shallow. From Braddock Heights the beautiful Middletown Valley, containing the village of Middletown, spread out before us to a distance of about eight miles, bounded by the Blue Ridge in the distance. The soils in this valley were essentially Chester soils.

We next crossed the wooded Blue Ridge from the top of which we had a fine view of the Great Valley to the west. The soils in this region were all derived from limestone. In fact, the valley developed because the limestone weathered faster than the crystalline rocks to the east and to the west of it. Hagerstown silt loam was the predominating soil type. This whole section showed great prosperity, indicating that it had a very productive soil.

Between Frederick and Hagerstown another of our automobiles broke

down and its occupants had to wait for one of the busses to return from Hagerstown for them. Because of these mishaps we were somewhat delayed in the arrival at Hagerstown, where we were due to arrive at noon. The local Chamber of Commerce gave us a fine luncheon and did valiant work in keeping it warm from two to four hours for us. The Mayor gave the address of welcome which was responded to by Dr. Wolf, of Germany, for the foreign delegates, and by Dr. Stevenson, of Iowa, for the American delegates.

After the luncheon we visited a splendid general and dairy farm a few miles out of this town. There we dug a pit in the Hagerstown silt loam. Its profile was very similar in color to that of the Chester loam. However, we found it to be lower in coarse material and higher in fine material than the latter. The disintegrated limestone was only about 4 feet from the surface. Road cuts in this soil had been selected for observations, but as it had rained heavily two days before the route had to be changed at the last moment.

We went from Hagerstown in a southwesterly direction, crossing the Potomac at Williamsport, Maryland, into West Virginia. For about the first half of the distance from the Potomac River to Martinsburg, we passed through a belt of thin shale soils which was very hilly and wooded. The rest of the way led through fertile limestone soils.

From Martinsburg to Winchester, Virginia, our route lay through a beautiful limestone country containing many large, well kept apple orchards. We reached Winchester at dusk, or about 8:00 o'clock. Dinner was served to us at the George Washington Hotel. The Presbyterian minister of this thriving village gave the address of welcome which was responded to by Dr. Alway from Minnesota.

Our caravan left Winchester at about 10:00 o'clock that night, crossed the Shenandoah River about ten miles southeast of Winchester, and the Blue Ridge at the village of Paris. Eastward the highway led us through Upperville, Atoka, Middleburg, Chantilly, Fairfax and thence to Washington. We arrived all the way from 2:00 A.M. till daybreak. Thus with us the song was literally true "We won't be home till morning."

GENERAL SESSION

Fifth Day—Friday, June 17, 1927

9:30 A.M.—The entire morning was devoted to a general session at which four chief addresses were delivered.

SOIL LEACHING

Dr. A. A. J. de'Sigmond presented an extensive report of his investigations and the findings of others upon this subject.

THE CHEMICAL CHARACTERISTICS OF SOIL LEACHINGS

Dr. A. A. J. de'Sigmond

Introduction

Credit is to be given the late Prof. E. W. Hilgard for first pointing out the characteristic effect of climate on the chemical composition of soils (8). On the other hand the Russian school of agronomists have independently developed their genetic soil classification and have thrown new light onto leaching processes in different media. Prof. Dr. K. D. Klinka, the honored member of the International Society of Soil Science, treats very lucidly the processes of soil leaching in acid and alkaline media, in his well-known book, "The Types of Soil Formation" (7). Prof. K. K. Gedroiz, of Leningrad, points out in his paper, "The Absorbing Complex of Soil and the Absorbed Soil Cations as a Basis of Genetic Soil Classification" (6), the characteristic effect of the absorbing complex and the absorbed soil cations on the chemical and physical properties of some typical soil formations, such as chernozem, saline and alkaline soils, podsol, and laterite. I myself was studying years ago the chemical characteristics of different soil types and was led to the conclusion that, when we make complete analyses of entire soil profiles, we not only obtain characteristic evidence as to the chemical composition of different soil types, but we may also trace the effect of different processes of leaching and disclose some chemical characteristics of these soil-leaching processes themselves.

From a chemical point of view we may distinguish three different types of soil leaching: the acid, the neutral (in the case of chernozem soils), and the alkaline (in the case of saline or alkali soils). I do not intend to discuss all the data available in the literature on this subject. I am also aware that all these data, as well as the new contributions I shall report later on, are as yet far too insufficient to serve as a basis for general conclusions. I shall simply endeavor to demonstrate, by some characteristic examples, what are the chief chemical characteristics of the three soil-leaching processes mentioned above. At the same time I shall show the importance of the complete chemical analysis of concentrated hydrochloric acid extracts of soil, as well as of the determination of the exchangeable cations and the degree of saturation of the soil. The aim of this discussion is to encourage other soil chemists to cooperate in work along this line, and to convince agrogeologists as to the great importance of similar analysis.

Soil-leaching in Acid Medium

In the environment of Budapest, on the right side of the Danube, we have a natural timberland in the part called "Hüvösvölgy" which was

formed on an original loess deposit. It represents a mixed forest of *Quercus sessiliflora* and *Carpinus betulus*. Under the perpetually moist humus cover of deciduous leaves we find a light gray horizon, about 8 cm. deep, that we may call the eluvial or podsolized horizon, A. At a depth of about 20 to 80 cm. we find a slightly red illuvial or accumulation horizon, B_1, followed at 80 to 100 cm. by a darker red illuvial horizon, B_2, representing the deeper part of the whole accumulation horizon from 20 to 100 cm. At a depth of about 120 cm. we strike the top of the original loess which was found not far from the plot in an open crack in its original condition. This loess was sampled and represented as horizon C, or original regolite, in the following tables. The acidity of the four horizons was determined by different methods as summarized in Table 1.

Table 1.—Acidity of the Hűvösvölgy soil, by different methods

Horizon	pH (quinhydrone electrode)		Titration acidity	
	in water	in N KCl	according to Daikuhara-Kappen with N KCl	with N sodium acetate
A	5.9	4.3	10.5	20.9
B_1	5.8	4.7	1.5	8.3
B_2	6.7	4.4	0.8	5.3
C	8.1	7.5	0.15	0.6

It is evident from the above data that the actual acidity of horizon A is still maintained in horizon B_1, that in horizon B_2 the reaction is approaching the neutral point, whereas horizon C belongs already in the alkaline zone of pH values.

We find very instructive figures in the pH values of the suspensions in normal potassium chloride. There is a striking increase of acidity not only in horizons A and B_1, but even in B_2. This fact is not in direct harmony with the two titration acidities, as the exchange acidity, according to the Daikuhara-Kappen method falls very rapidly and does not correspond with the pH values in normal potassium chloride suspension in horizons B_1 and B_2. The discrepancy for the hydrolytic acidity is less evident, but still to be noted.

We have determined the state of saturation according to Dr. D. J. Hissink (10) using the formula,

$$V = \frac{100 \cdot S}{T}$$

in which V represents the degree of saturation, S the total equivalents of cations, and T the maximum equivalent of absorption. This represents

theoretically the complementary value of the term of K. K. Gedroiz (5) for the degree of unsaturation of the soil with respect to bases. The value S was determined by adding the equivalents of the single exchangeable cations, determined by the method of Hissink (9). However, for the determination of the unsaturated portion of the absorption complex, that is the absorbed "active" hydrogen, we used the conductometric titration method with 0.1 N barium hydroxide according to Dr. E. M. Kolthoff (14). This method and the arguments supporting it are reported in another paper: "Different degrees of saturation of the absorptive complex (humus-zeolite) and their determination." Table 2 reports the respective data.

The absorbed hydrogen, or "active" hydrogen equivalents, are nearly in complete harmony with the pH values in water, and normal potassium chloride suspension. But we may notice at the same time, that according to the above data, horizon C though alkaline in reaction, is still unsaturated, the absorption complex having 9.6 equivalents of hydrogen absorbed, and thus the degree of saturation, $V = \frac{100 \cdot S}{T}$, is 70.8 or conversely the degree of unsaturation 29.2.

From these analytical results it is evident that the three horizons (A, B_1 and B_2) are more or less acid and correspondingly unsaturated. The eluvial horizon possesses, besides, a high titration acidity, in full accordance with Kappen's theory of soil-leaching in acid medium. At the same time we have here some evidence, which proves that in the upper soil-horizons were prevailing soil-leaching processes similar to those taking place if we leached the soil permanently with a dilute acid solution.

We have made several experiments with fully saturated artificial zeolites, by treating them with pure water saturated with carbon dioxide until all the exchangeable bases were removed from the absorption complex. The same process can be supposed to wash out the exchangeable bases of the original absorption complex of the soil in the above soil profile. The T-value of the original loess-horizon is slightly less than those of the horizons A, B_1, and B_2, because the acid soil solution is also decomposing other compounds of the original loess, and thus the absorption complex accumulates in the three upper horizons. To get a full view of the leaching process prevailing we must know also the chemical composition of the concentrated hydrochloric acid extract of the soil.

The soil extract was made according to the van Bemmelen-Hissink method proposed at the Fourth International Conference at Rome, and the analytical results are given in Table 3.

In comparing first the three upper horizons (A, B_1 and B_2) we may notice at once, a leaching out of bases and an accumulation of the insoluble portion in the A-horizon, corresponding with the accumulation of bases in the B_1- and B_2-horizons and a diminution of the insoluble portion.

TABLE 2.—State of saturation of the Hürösrölgy soil, in milligram equivalents

Horizon	Exchangeable					S= total cations	Absorbed H "active"	T= capacity of absorption	$V=\frac{100 \cdot S}{T}$, degree of saturation
	Al	Ca	Mg	Na	K				
A	0.9	4.61	6.27	0.64	2.2	14.62	20.0	34.62	42.2
B_1	0.7	6.96	5.21	1.24	2.12	16.23	18.0	34.23	47.4
B_2	0.5	10.66	3.5	1.37	2.53	18.56	17.6	36.16	51.5
C		16.32	3.2	1.68	2.10	23.30	9.6	32.90	70.8

TABLE 3.—Chemical composition of the hydrochloric acid extract of the profile of the Hüvösvölgy soil; as per cent of dry soil

	Horizon			
	A	B_1	B_2	*C*
Na_2O	0.39	0.41	*0.44*	0.35
K_2O	0.57	*0.59*	0.51	0.61
CaO	0.60	*1.91*	1.67	8.95
MgO	0.80	0.81	*1.24*	3.60
MnO	0.28	*0.55*	0.07	0.94
Fe_2O_3	1.59	2.59	*2.97*	3.41
Al_2O_3	3.75	4.69	*7.50*	3.03
SO_3	0.39	0.29	*0.47*	0.35
P_2O_5	0.06	0.08	*0.13*	0.12
CO_2				7.94
SiO_2 soluble in concd. HCl and 5% KOH	8.94	9.43	10.68	6.09
Loss on ignition	4.51	3.87	4.52	3.76
Insoluble	*77.21*	74.41	70.26	61.11
Total	99.99	99.63	100.46	100.27

As a whole, this is the reason why we call the horizons B_1 and B_2 accumulation horizons. The figures in italics represent the maximum values for the three upper horizons.

When on the other hand we compare the composition of the *C*-horizon, with that of the *A*-, B_1-, and B_2-horizons we may conclude that, even in the case of the accumulation horizons B_1 and B_2 calcium, magnesium, and carbonate are in some way leached out. That means, that the acid soil water, having gradually dissolved the calcium carbonate and magnesium carbonate of the upper horizons, carried them into the substrata of the soil. But furthermore we have evidence in Table 3, proving the transportation of ferric oxide, alumina, and soluble silica from the eluvial horizon *A* into the B_1- and B_2-horizons. This can be done partly mechanically, as sols of ferric oxide, alumina, silica or zeolites, and partly by the reduction of ferric oxide to ferrous oxide and combination with humic acids. In order to know which part of the alumina and silica was in a free colloidal state, and to get some evidence as to the degree of decomposition of the zeolites in the soil, we treated the original soil samples with a 5 per cent solution of potassium hydroxide at a temperature of 55° C. for 5 minutes, in full agreement with the treatment of the residue with hydrochloric acid. The respective analytical data are represented as follows:

Horizon	SiO_2 per cent	Al_2O_3, per cent soluble in 5 per cent potassium hydroxide
A	1.57	0.60
B_1	2.02	0.48
B_2	1.90	0.46
C	1.51	0.46

As I have repeatedly tested the artificial zeolites and have found them resistant to dilute alkali hydroxides, I feel entitled to assume that the silica and alumina, dissolved by the above treatment of the original soil sample, represent approximately the amorphous silicic acid and alumina present in the soil. Gedroiz points out, in his recent paper on the absorbing complex of the soil (6), that he has not detected in podsol soils any considerable quantities of silicic acid soluble in 5 per cent potassium hydroxide. The maximum figure he mentions was 1.5 per cent silicic acid, while for alumina he obtained figures which considerably exceed the quantity of silicic acid. He also quotes an example: In the 15 to 30 cm. horizon of a podsol soil of Ochten Forestry there were 1.05 per cent SiO_2 and 2.72 per cent Al_2O_3. Though he will not affirm that the process of podsolization is still accompanied by an accumulation of amorphous aluminum oxide, he nevertheless remarks, that in the process of podsolization, he could not demonstrate the accumulation of amorphous silicic acid. The above figures do not confirm the theory of Gedroiz, as in the horizons B_1 and B_2 we apparently have to do with some moderate accumulation of amorphous silicic acid; moreover, contrary to the quoted figures of Gedroiz, the quantity of amorphous aluminum oxide is far less than that of silicic acid. If we calculate the amorphous silicic acid as per cent of the total soluble silica of Table 2, we get the following data:

Horizon	Amorphous SiO_2 as per cent of total soluble SiO_2
A	17.5
B_1	21.4
B_2	17.7
C	24.8

If we calculate from the figures of Table 3 the respective equivalents and their per cents according to my suggestion, already proposed in my paper: "Different degrees of saturation of the absorptive complex (humus-zeolite) and their determination," and used since that time always successfully, we get the chemical characterization of the hydrochloric acid decomposable part of the soil, as it is represented in Table 4.

In considering the figures of Table 4, we see that the original loess was very rich in carbonates. As the total equivalent-per cent of calcium is but 37.39, it is evident that at least 4.77 equivalent-per cent of magnesium was combined with carbonate. But, as we shall see later on, we might compute more magnesium carbonate in the original loess. The amount of the positive monovalent cations is relatively low, in sum 2.8 equivalent-per cent.

On the other hand in the horizons A, B_1 and B_2 the carbonates are totally deficient and in correspondence with this, the equivalent per cent of the bivalent cations is considerably diminished. Consequently we might assume the latter to be leached out to a higher degree than the monovalent cations.

TABLE 4.—Milligram equivalents of ions in the hydrochloric acid extract, calculated as per cents of the total milligram equivalents; Hüvösvölgy soil

		Horizon				
		A	B_1	B_2	*C*	
Total mg. equivalents of the cations		376.52	523.26	*696.39*	865.75	
Equivalent % of the total	Na^{I}	*3.32*	2.53	2.03	1.3	
	K^{I}	*3.20*	2.39	1.55	1.5	
	Ca^{II}	5.67	*13.06*	8.55	37.39	
	Mg^{II}	*10.56*	7.68	8.82	20.30	100%
	Mn^{II}	2.10	*2.97*	0.28	3.10	
	Fe^{III}	15.85	*18.69*	15.91	15.02	
	Al^{III}	59.30	52.68	*62.85*	20.79	
	SO_4^{II}	*2.16*	1.10	1.40	0.87	
	PO_4^{III}	0.68	0.85	0.80	0.59	
	CO_3^{II}				42.16	100%
	SiO_4^{IV}	97.16	98.05	97.80	47.18	
	Om^{II}				9.20	
Surplus of SiO_2 (soluble), equiv. in 100 g. dry soil		3.46	1.74	0.32		

Now if we combine the figures of Tables 4 and 2, we can calculate how many milligram equivalents of the constituents, decomposed by concentrated hydrochloric acid, are exchangeable. The respective data are reported in Table 5. In considering these results, we arrive at some interesting conclusions relative to the soil-leaching process prevalent in the present case.

These experimental data are very interesting indeed, as regards the effect of acid soil-leaching on the original loess (horizon *C*). There is a striking difference in the behavior of the total bivalent and monovalent cations, as represented in the first column of Table 5. Notably the calcium and magnesium dissolved by concentrated hydrochloric acid decrease gradually in the direction of the surface of the soil. On the contrary the acid-soluble potassium hardly changes materially through the whole column of the soil profile, and the sodium is likely to show some accumulation as compared with the original loess. Before drawing our conclusions as to the effect of acid soil-leaching, we have also to consider the figures of the second and third columns. In the second column we see the quantity of exchangeable cations expressed in milligram equivalent values, as this is the only reliable basis for comparison of the different cations.

Here we may notice a behavior of the exchangeable cations quite different from that which we have pointed out for the total amount dissolved by concentrated hydrochloric acid. Starting again from the

TABLE 5.—Relation of exchangeable to total cations of the hydrochloric acid extract; Hüvösvölgy soil

Cation	Horizon	Total dissolved by concd. HCl	Exchangeable	Exchangeable, as per cent of total cations dissolved by concd. HCl
		mg. equiv.	mg. equiv.	
Ca	A	21.4	4.61	21.75
	B_1	68.2	6.96	10.20
	B_2	59.6	10.66	17.85
	C	320.0	16.32	5.10
Mg	A	39.76	6.27	15.77
	B_1	40.21	5.21	12.95
	B_2	61.42	3.50	5.69
	C	175.75	3.20	1.82
K	A	12.10	2.20	18.18
	B_1	12.52	2.12	16.90
	B_2	11.82	2.50	21.40
	C	12.95	2.10	16.20
Na	A	12.58	0.64	5.08
	B_1	13.93	1.24	9.38
	B_2	14.20	1.37	9.65
	C	11.30	1.68	14.85

original loess (C-horizon) to the surface eluvial horizon A we notice a gradual and rather considerable decrease of magnesium cation. The exchangeable potassium hardly changes, whereas we find a slight decrease in sodium. This proves undoubtedly that by soil-leaching in acid medium the exchangeable calcium cation is attacked to a greater extent, and then to a somewhat lesser degree the exchangeable sodium, whereas the exchangeable potassium hardly changes. As regards the exchangeable magnesium cation we have to admit a remarkable accumulation. To throw light upon this unexpected accumulation of exchangeable magnesium cation I might undertake some calculation as to the probable amount of magnesium carbonate in the original loess (horizon C).

Starting with the supposition that the acid leaching effect in horizon B_2 is attenuated to the point where it no longer attacks the cations which are in combination with silicates, and are more resistant to acids than the exchangeable cations of the absorption complex, we are entitled to suppose that the amount of those cations in horizon B_2 represents about the amount of cations of the same category in horizon C also. Subtracting the exchangeable calcium and magnesium from the totals of the respective

cations, dissolved by concentrated hydrochloric acid, we find for magnesium 57.92 mg. equiv. and for calcium 48.94 mg. equiv., combined as silicates more resistant to acids. In a similar way, as regards the *C*-horizon, we get for magnesium, 172.55 mg. equiv. and for calcium 303.68 mg. equiv. But both values comprise the carbonates also. If, now, we subtract in this case the respective figures for magnesium and calcium of horizon B_2 from these latter we get 114.63 mg. equiv. magnesium and 254.74 mg. equiv. calcium as combined with carbonate. Though it may seem arbitrary, this assumption is supported by the fact that the calculated sum of the two carbonates represents 369.37 mg. equiv., that is 42.7 per cent of the sum of negative equivalents. In reality we have found, according to Table 4, the experimental value of 42.16 per cent mg. equiv. of carbonate. The coincidence of the two figures is so striking that I feel there is some confirmation of the above-detailed suppositions. As we have no reliable method for the magnesium carbonate and calcium carbonate separately, we may be satisfied with this coincidence and justified in computing that in the original loess about two-thirds of the carbonates consisted of calcium carbonate and one-third magnesium carbonate. W. H. MacIntire (16) has developed a theory, according to which the magnesium carbonate may be deficient in the soils of humid climate. Hissink has found similar evidence in Holland (9). I cannot confirm this by my own experience with different Hungarian soils (20) and the present case proves again that we are not entitled to generalize this thesis. Moreover we have to investigate each soil separately in this respect.

In the third column of Table 5 we have the relative values of the exchangeable cations per 100 parts of the total cations dissolved by concentrated hydrochloric acid. It is interesting to note that with the exception of the sodium, the exchangeable fraction of the total is relatively much higher in the leached horizons, than in the original (*C*). This fact may be connected with the supposition that the sodium absorbed by the original zeolite complex of the loess was attackable in higher degree than the sodium combined otherwise. In the case of potassium, we do not find such evidence. It seems that by the process of leaching in acid medium, the potassium is far more strongly retained by the absorptive complex than the sodium. This is, as we shall see later on, a very striking difference between the process of leaching in acid and in alkaline medium.

If now we want to consider, as a whole, the chemical changes which occurred in the absorbed cations, as a result of the acid soil-leaching, we have to calculate the milligram equivalents of Table 2 in per cents of the total exchangeable cations (*S*). The figures in Table 6 represent the respective values.

At first glance we note that in the original loess there was no exchangeable aluminum, which cation seems to enter into the absorption complex in the case of the acid soil solution. This agrees with the experience of

W. P. Kelley (12) who has found in the case of American acid soils considerable amounts of exchangeable aluminum and iron.

TABLE 6.—Milligram equivalents of individual exchangeable cations, expressed as per cents of total milligram equivalents (S); Hűvösvölgy soil

Horizon	Al	Ca	Mg	Na	K
A	6.1	31.5	43.0	4.4	15.0
B_1	4.3	43.0	32.0	7.7	13.0
B_2	2.7	57.4	18.8	7.4	13.7
C		70.0	13.7	7.2	9.1

On the other hand, we see a very marked leaching out of calcium in the absorptive complex, and a slight leaching out of sodium, but a very remarkable accumulation of magnesium and, in a more moderate degree, of potassium. It seems as if the magnesium and potassium have partly displaced the calcium and sodium of the complex. At the same time, it is evident, that it is not reliable to determine, as Hissink suggested (11), the total (*S*) by determining simply the exchangeable calcium in the soil. It is true, that, in most of the cases, the exchangeable calcium averages approximately 70 to 80 per cent but we can run the risk of a very serious error sometimes, if we determine only the exchangeable calcium, and reckon the *S* by computing 80 per cent of calcium as exchangeable in it.

Now if we are to get a complete idea of the absorption complex, we must consider also the absorbed hydrogen determined by conductometric titration. The analytical data are already given in Table 2, but it is shown more instructively if we calculate the whole absorption complex as per cents of the total *T*-value, that is the total absorption capacity of the soil. We may find the respective data in Table 7.

TABLE 7.—Relation of exchangeable cations to total absorption capacity

Horizon	*T*	Mg. equivalents of exchangeable cations, as per cent of total absorption capacity (*T*)						*S*	*V*
		Al	Ca	Mg	Na	K	H		
	mg. equiv.							mg. equiv.	
A	34.62	2.60	13.30	18.10	1.85	6.35	57.80	14.62	42.2
B_1	34.23	2.03	20.32	15.23	3.62	6.20	52.60	16.23	47.4
B_2	36.16	1.43	29.50	9.68	3.79	7.00	48.60	18.56	51.4
C	32.90	0.00	49.60	9.74	5.10	6.36	29.20	23.30	70.8

As I know, this is the first attempt to reproduce the full absorption complex. Gedroiz in his paper on unsaturated soils undertook a similar

reproduction (5, p. 21) but his determinations are not so complete (as sodium and potassium are deficient) and his method of determination of the absorbed hydrogen is very uncertain, as we will show in another paper.

It seems to me very instructive to see how the hydrogen displaced the other cations from the *T*-complex, especially the calcium and in second place the sodium also. As regards the potassium, there is no material change in the different horizons, except a slight increase in the B_2-horizon. But the per cent of magnesium shows a very marked increase towards the surface. I am inclined to assume that the rôle of magnesium is here an exceptional one, and probably due to the considerable magnesium carbonate content of the original soil.

As is evident from the above figures, we see that the chemical composition of the absorptive complex (zeolite-humus) seems to be very characteristic for the soil-leaching process, and if we want to develop more extensively our chemical knowledge in this respect, we should endeavor to obtain more analytical material in a similar way.

I may mention here the result of another acid soil-profile, in which we investigated only the absorptive complex. This is a peat soil at Csikovár, not far from Budapest. We sampled but four horizons, as follows:

Horizon	Depth cm.	Characteristics
I	0–8	Light gray eluvial horizon
II	8–30	Darker gray, a transition from horizons I to III
III	30–40	Dark gray horizon
IV	40–58	Do as the bottom with lodging water

The acidity figures are presented in Table 8.

TABLE 8.—Acidity of the Csikovár peat soil

Horizon	pH of suspension		Titration acidity	
	In water	In *N* KCl	Daikuhara-Kappen with *N* KCl	With Na acetate
I	5.01	4.32	2.2	25.8
II	5.75	4.48	1.8	15.1
III	6.14	4.99	0.7	10.0
IV	6.49	5.48	0.3	6.4

The respective figures for the exchangeable bases and the state of saturation are collected in Tables 9, 10 and 11.

Apparently in this case the displacing of the cations is not as extensive as in the case of the soil of Hüvösvölgy. But we should not forget that in this case the sampling and analysis of the original soil (horizon *C*) was impossible because the water level in the soil was too high.

TABLE 9.—Exchangeable bases and state of saturation of Csikovár peat soil, in milligram equivalents

Horizon	Exchangeable cations					Absorbed H (active)	Capacity of absorption T	Degree of saturation $V=\frac{100 \cdot S}{T}$
	Ca	Mg	K	Na	Total= S			
I	10.9	5.1	0.8	1.3	18.1	15.9	34.0	53.2
II	11.4	4.0	1.1	1.7	18.2	14.2	32.4	56.2
III	11.8	4.3	1.4	1.8	19.3	12.7	32.0	60.4
IV	11.2	4.2	1.2	2.1	18.7	11.5	30.2	61.9

TABLE 10.—Milligram equivalents of individual exchangeable cations, expressed as per cents of total milligram equivalents (S); Csikovár peat soil

Horizon	Ca	Mg	Na	K
I	60.2	28.2	7.2	4.4
II	62.6	22.0	9.3	6.1
III	61.2	22.3	9.3	7.2
IV	60.0	22.4	11.2	6.4

TABLE 11.—Relation of exchangeable cations to total absorption capacity; Csikovár peat soil

Horizon	T	Mg. equivalents of exchangeable cations, as per cent of total absorption capacity (T)					S	V
		Ca	Mg	Na	K	H		
	mg. equiv.						mg. equiv.	
I	34.0	32.1	15.0	3.8	2.3	46.8	18.1	53.2
II	32.4	35.2	12.3	5.3	3.4	43.8	18.2	56.2
III	32.0	36.9	13.4	5.7	4.4	39.6	19.3	60.4
IV	30.2	37.1	13.9	6.9	4.4	38.1	18.7	61.9

Soil-Leaching in So-Called Neutral Medium

Before starting the report on the respective analytical results, I should like to shed some light first upon what we may understand by the so-called neutral medium. Theoretically we accept as neutral all solutions with a pH of 7 or approximately that. But with soils and soil solutions this definition is not always reliable, because we have numerous data which prove that soils with a pH of 7, or approximately 7, are not always neutral in a chemical sense. The explanation is easy to understand if we compare the pH value of a solution of a neutral salt in which the cation as

well as the anion are so-called strong components, for example in the case of calcium chloride. The water solution of this chemically neutral salt is equally neutral, and will show a pH of about 7. But if we mix, for instance, pure calcium carbonate with pure water, both which compounds are of themselves chemically neutral, the pH of the solution will run about 8 to 8.4 because the dissolved portion of the calcium carbonate will hydrolize and we shall get in the solution a strong base, calcium hydroxide, a weak acid, carbonic acid, and their respective ions. Now, as the calcium hydroxide increases the hydroxyl ion concentration of the water solution to a much higher degree than the weak carbonic-acid increases the hydrogen ion concentration, there will result a solution with a pH of about 8. We may get the same reaction with calcium acetate, calcium borate, tricalcium phosphate, calcium malate, pure and saturated calcium zeolite, and with all chemically neutral calcium salts, in which the negative ion is a weak acid radical. Consequently if we have a soil in which calcium carbonate or magnesium carbonate and saturated humus-zeolite-complex are dominant, we will get a pH around 8 and not the above theoretical value, pH 7.

In the acid soils treated above, we might have noted that, in the case of the timber-soil of Hüvösvölgy, the B_2-horizon had a pH of 6.7 in water suspension (see Table 1) and yet was acid and highly unsaturated (see Tables 2 and 7). Moreover the original loess (*C*-horizon) subsoil of the same soil-profile, has a pH of 8.1 in water suspension and yet its behavior is likely to tell us of some moderate latent acidity (see the figures in Table 1) and we could still determine some hydrogen in the absorptive complex (see Tables 2 and 7). It is easy to understand that the active pH value of the soil-water suspension is the ultimate result of different reactions and is determined by the ratio of hydrogen and hydroxyl ions in the water suspension. In the case of the loess horizon (*C*) we see in the absorptive complex *T* (Table 7), besides 49.60 equivalent-per cent of calcium and 9.44 equivalent-per cent of magnesium, 5.10 equivalent-per cent of sodium and 6.36 equivalent-per cent of potassium. The latter alkali components of the absorptive complex are likely to paralyze the acid effect of the absorbed active hydrogen (29.20 equivalent-per cent); consequently we get a pH of 8 although the soil is really in a chemical sense not neutral and is unsaturated with bases. For that reason, the pH value in soil-water suspension of itself is not sufficient to determine the real chemical reaction of the soil, or soil solution. Hence we are not justified in estimating the reaction of the soil, or soil solution, simply by determining the pH value. This is also the reason why the method of Gedroiz for determining the degree of unsaturation (5, p. 21) cannot be reliable; and consequently the results of his respective analytical investigations seem to me erroneous. We shall treat this question separately in another paper.

Gedroiz comes to about the same conclusion for the chernozem type of

soil formation (6, p. 5), pointing out, that with the corresponding genetic factors the result will be a soil with an absorbing complex fully saturated with bases, not containing any absorbed hydrogen ion, and with the base calcium absorbed to a greater extent, and magnesium to a lesser extent, sodium and potassium being deficient. I think this latter claim of Gedroiz is somewhat exaggerated and based on the supposition that the slight quantities of alkalies, determined by the base exchange in this case, are due to the base displacement of nonzeolitic silicates (4), which supposition is not exactly proved and verified. It is true, that some unweathered alkali silicates, when treated with normal ammonium chloride, will exchange some alkali cations, but we have no accurate basis, upon which to draw the correct limits between the cations exchanged by the fresh silicates and by the zeolite complex, when both are present. Consequently we have to consider the total quantity of the exchanged cations, without using any arbitrary selection. I find also that the other claim of Gedroiz, in regard to the absolute absence of hydrogen in the absorptive complex, is too rigid and supported by the erroneous method suggested by Gedroiz for the determination of hydrogen absorbed by the soil (5, p. 21). We have found by very extensive analytical studies, that the only way to get a reliable measure for that value is the conductometric titration with 0.1 N barium hydroxide. All other methods suggested by others for this purpose proved erroneous, as we might show separately in another paper.

TABLE 12.—Chemical composition of the hydrochloric acid extract of the profile of the Csorвás chernozem soil, in per cent of dry soil

	Horizon		
	A 0–18 cm.	B_1 60–80 cm.	B_2 100–120 cm.
Na_2O	0.13	*0.15*	*0.15*
K_2O	*1.23*	1.18	0.92
CaO	3.28	5.21	*9.91*
MgO	1.75	1.84	*2.26*
MnO	*0.09*	0.08	0.08
Fe_2O_3	4.92	*4.96*	4.64
Al_2O_3	*8.26*	8.12	6.97
SO_3	*0.08*	0.07	0.06
P_2O_5	*0.20*	0.18	0.13
CO_2	0.47	2.15	*6.67*
SiO_2 soluble in concd. HCl and 5% Na_2CO_3	*6.05*	5.96	5.40
Humus	*6.08*	5.51	2.52
H_2O chem. combined	*4.56*	4.37	4.12
Insoluble residue	*62.70*	60.23	56.17
Total	99.80	100.00	100.00

Now after getting this experience, and working out our method exactly we were struck by the fact that, among the soils we had investigated, we found very few in which there was no absorbed hydrogen at all. In Table 12 we have the chemical composition of the hydrochloric acid extract of the soil profile of a Hungarian chernozem of dark brown color, at Czorvás, in the county Békés. This soil profile was sampled and analyzed by Dr. Robert Ballenegger (3) and the results are taken from the original paper. From these figures we have calculated the respective milligram equivalents and their per cents of the total cation equivalents as before, according to my system. The data of this calculation are given in Table 13.

TABLE 13.—Milligram equivalents of ions in the hydrochloric acid extract of the Csorvás chernozem soil, calculated as per cent of the total milligram equivalents

		Horizon			
Total mg. equivalents of cations		*A*	B_1	B_2	
		906.6	973.0	1076.5	
Equivalent % of the total	Na^{I}	0.46	*0.48*	0.44	100%
	K^{I}	*2.89*	2.58	1.82	
	Ca^{II}	12.93	19.30	*32.90*	
	Mg^{II}	9.57	9.25	*10.40*	
	Mn^{II}	*0.03*	0.02	0.02	
	Fe^{III}	*20.32*	19.17	16.26	
	Al^{III}	*53.80*	49.20	38.16	
	SO_4^{II}	*0.22*	0.19	0.14	100%
	PO_4^{III}	0.93	0.78	0.49	
	CO_3^{II}	2.38	10.10	28.15	
	SiO_4^{IV}	44.20	40.70	33.22	
	Om^{II}	52.27	48.23	38.00	

At first sight we might conclude that, in spite of the marked leaching down of alkaline-earth carbonates, the rest of the acid-decomposable components do not change considerably, and there is more of an accumulation in the surface horizon, *A*, to note. The other evidence, proving that the soil belongs to the chernozem type, may be found in the original paper of Ballenegger.

Now let us see what is the reaction number in the different horizons, and whether there is any hydrogen absorbed. The corresponding figures we find in Table 14.

As is evident, and in harmony with the above considerations, the pH of the soil-water suspension runs over 8 and that with normal potassium chloride 7.5. According to this we might term the three horizons neutral. But only the B_2-horizon is fully saturated; the others are slightly unsaturated. It follows from this that, under the climatic conditions prevailing

TABLE 14.—Reaction and absorbed hydrogen of the Csorvás soil profile

Horizon	pH of suspension		Absorbed H
	In water	In N KCl	
A	8.04	7.60	8.7
B_1	8.20	7.49	5.6
B_2	8.69	7.62	0.0

there, the surface horizons are slightly unsaturated, and the calcium carbonate and magnesium carbonate are in notable degree washed down.

As regards the exchangeable bases we obtained the figures given in Table 15.

TABLE 15.—Exchangeable cations of the three horizons of the Csorvás soil

	Horizon	Ca	Mg	K	Na	Total $= S$
Exchangeable cations in mg. equiv.	A	25.14	1.25	1.02	0.80	28.21
	B_1	24.29	2.14	1.25	1.10	28.78
	B_2	18.58	0.63	1.00	3.50	23.71
Exchangeable cations in % of the total (S)	A	88.8	4.8	3.6	2.8	100
	B_1	84.5	7.4	4.3	3.8	100
	B_2	78.4	2.7	4.2	14.7	100

TABLE 16.—Relation of exchangeable cations to total cations of the hydrochloric acid extract of the Csorvás chernozem soil

Cation	Horizon	Total dissolved by concd. HCl	Exchangeable	Exchangeable as per cent of total cations dissolved by concd. HCl
		mg. equiv.	mg. equiv.	
Ca	A	117.0	25.14	21.4
	B_1	186.0	24.29	23.1
	B_2	354.0	18.58	5.25
Mg	A	86.7	1.25	1.44
	B_1	91.0	2.14	2.35
	B_2	112.0	0.63	0.56
Na	A	4.2	4.7	4.7
	B_1	0.8	1.1	3.5
	B_2	19.0	23.4	74.5
K	A	26.2	25.1	19.6
	B_1	1.02	1.25	1.0
	B_2	3.9	4.98	5.1

It is worthy of mention that there is some accumulation of calcium in horizons A and B_1 rather than a washing out, whereas the exchangeable sodium is considerably reduced. Here we might agree with Gedroiz, that aside from the B_2-horizon the alkali cations are negligible; the magnesium also does not play any noteworthy rôle. The exchangeable calcium cation is so largely dominant that all the others are negligible. But in horizon B_2 the relatively high equivalent-per cent of sodium (14.7 per cent) is likely to indicate some alkalinity.

In Table 16 we may see the proportion of exchangeable cations in per cent of the total soluble in concentrated hydrochloric acid.

It seems to me quite instructive that the equivalent per cents of exchangeable calcium in the total calcium equivalent decomposed by concentrated hydrochloric acid, as well as the same figures for sodium, are very considerable, and for calcium they would be even higher, if we could calculate the calcium carbonate equivalents and subtract from the total. If we try this, arbitrary though it is, we get much higher values as follows:

Horizon	Total carbonated calcium	Exchangeable calcium	Exchangeable as per cent of total carbonated calcium
A	95.6	25.14	26.3
B_1	88.2	24.29	27.5
B_2	51.0	18.58	36.4

It would be more reliable, if we could calculate also the distribution of magnesium in the carbonates, but this is hardly possible here. However we might treat horizon A as entirely free of magnesium carbonate and attribute the gradual increase of magnesium with depth to magnesium carbonate. We then get in horizon B_1 4.3 equivalents, in horizon B_2 25.3 equivalents of carbonates contributed by magnesium; and, adding these values to those of the corresponding calcium values, we get for the total carbonated calcium in B_1 92.5, in B_2 76.3 equivalents. The respective per cents of exchangeable are 26.2 and 24.3, in B_1 and B_2 respectively. These latter figures agree better with the 26.3 per cent value of horizon A, than the values given above, supporting the reliability of the assumption of magnesium carbonate in B_1 and B_2.

Finally we get the chemical composition of the absorptive complex T as shown in Table 17.

We note at first the increase of T in horizons A and B_1 as compared with horizon B_2. It seems very likely that the more advanced weathering of the silicates near the surface and the enrichment in humus are responsible for this increase and not an accumulation of the absorptive complex by capillarity. This supposition is supported also by the relatively not negligible per cent of absorbed hydrogen in the above-mentioned (A and B_1) horizons, because it is hardly possible to attribute this evidence to some acid leaching process in the presence of the considerable amount of

alkaline-earth carbonates. We know that the starting point of silicate-weathering consists of hydration of the anhydrous silicates and by this phenomenon it is easy to assume hydrolytic processes as responsible for the unsaturated portion of the absorptive complex. In horizon B_2 evidently this hydrolysis may be less and the considerable increase of calcium carbonate protects the full saturation of the complex.

TABLE 17.—Relation of exchangeable cations to total absorption capacity; Csorvás soil

Horizon	T	Mg. equivalents of exchangeable cations, as per cent of total absorption capacity (T)					S	V
		Ca	Mg	K	Na	H		
	mg. equiv.						mg. equiv.	
A	36.91	68.1	3.4	2.8	2.2	23.5	28.21	76.5
B_1	34.38	70.7	6.2	3.7	3.2	16.2	28.78	83.8
B_2	23.71	78.4	2.7	4.4	14.7	0.0	23.71	100.0

This supposition is furthermore supported by the analytical data of another typical black chernozem at Pusztakamarás (county Kolozs) previously belonging to old Hungary, now to Rumania. A detailed description of the occurrence and morphology of the soil-profile is published in the above-cited paper of Ballenegger (3). I may point out just two essential statements. First, the genesis of the soil of the so-called "Prairie" of Translyvania, of which, that of Pusztakamarás is a typical representative, goes back to the pleistocene age. At that time there existed an arid climate in this part of the territory, the previous flora died, and a loess formation was deposited, on which a luxurious grass vegetation settled, coming, according to the investigations of Pax, from the East of Europe during and after the glacial age.

P. Kossowitsch in his German work (translated from the original Russian) on chernozem (15) points out, as a typical characteristic of the chernozem, that the chemical composition of the whole soil-profile, including the original rock, does not change materially; but there is an accumulation of humus in the surface A-horizon, and eventually a washing down of calcium carbonate if this existed in the original rock. The foregoing instance in the soil-profile of Czorvás was a typical representative of this type of chernozem. That of Pusztakamarás represents the other type of chernozem with an absolute deficiency of carbonates. Ballenegger emphasizes in his paper quoted (3), with the full analysis of the concentrated hydrochloric acid extract, the stability of the chemical composition of the whole soil-profile. And as the soil and original rock (the loess) was free of carbonates, the only difference consists in the humus content, as is evident from the analytical data of Ballenegger, given in Table 18. Furthermore we have calculated the original figures of Bal-

TABLE 18.—Chemical composition of the hydrochloric acid extract of the profile of the Pusztakamarás soil; as per cent of dry soil

	Horizon		
	A 0–20 cm.	*B* 80–100 cm.	*C* 120–140 cm.
Na_2O	0.41	0.31	0.30
K_2O	1.19	1.24	1.07
CaO	0.76	0.80	0.63
MgO	1.01	1.24	1.51
MnO	0.13	0.15	0.15
Fe_2O_3	5.43	5.71	5.58
Al_2O_3	9.04	9.94	9.04
SO_3	0.04	0.04	0.01
P_2O_5	0.07	0.07	0.07
CO_2			
SiO_2 soluble in concd. HCl and 5% Na_2CO_3	10.80	11.21	10.58
Humus	5.57	5.31	1.19
H_2O chem. combined	4.03	3.41	3.34
Insoluble residue	60.70	59.40	66.00
Total	99.18	98.43	99.47

lenegger to milligram equivalents and in per cents of the total milligram equivalents of cations. The latter figures are collected in Table 19 and indicate again that we have to do here with a soil not changing in its chemical composition through the whole profile. This proves moreover that the soil sample represents a real chernozem deficient in carbonates.

TABLE 19.—Milligram equivalents of ions in the hydrochloric acid extract of the Pusztakamarás soil, calculated as per cent of total milligram equivalents

Total mg. equiv. of cations		Horizon *A* 854.9	*B* 929.0	*C* 875.0	
Equiv. per cent of the total	Na^{I}	1.55	1.08	1.11	100 %
	K^{I}	2.97	2.84	2.60	
	Ca^{II}	3.17	3.08	2.56	
	Mg^{II}	5.85	6.61	8.55	
	Mn^{II}	0.43	0.45	0.48	
	Fe^{III}	23.80	23.00	23.90	
	Al^{III}	62.23	62.94	60.80	
	SO_4^{II}	0.12	0.11	0.03	100%
	PO_4^{III}	0.35	0.33	0.34	
	SiO_4^{IV}	83.60	79.80	80.00	
	Om^{II}	15.93	19.76	19.63	

The greater part of the chernozem of Russia, as quoted in Kossowitsch's book on chernozem, belongs to that type.

The data of Tables 18 and 19 indicate accurately that we have to do with a typical chernozem except for the fact that the humus content of the horizon *A* is somewhat lower than that of those in Russia.

The pH values and the equivalents of absorbed hydrogen are given in Table 20.

TABLE 20.—Reaction and absorbed hydrogen of the Pusztakamarás soil

Horizon	pH of suspension		Mg. equiv. H absorbed
	In water	In *N* KCl	
A	6.37	5.97	22.3
B	6.70	5.87	24.8
C	7.70	6.87	14.8

These results are surprising inasmuch as we would have suggested, according to the theory of Gedroiz, that the chernozem represents a fully saturated absorptive complex. The actual reaction of the water suspension is fairly neutral, but in normal potassium chloride suspension it is slightly acid and the absorbed hydrogen in the complex considerable enough. The fact that Gedroiz has found no hydrogen in similar Russian soils can be explained by this very example. By using methyl orange as an indicator in the method of Gedroiz, we will hardly get the pink color of an acid medium; consequently we should consider the soil saturated. But with the conductometric titration, which we are using in our laboratory, we have obtained abundant evidence to prove that the soil with a pH of 7 is not yet fully saturated with bases. It would be of general interest to test numerous Russian chernozem soils with this method, to shed light upon this apparent discrepancy.

We have determined the exchangeable cations and the degree of saturation, as well as the whole chemical composition of the *T*-complex, the respective figures being collected in Table 21.

In considering the quantity of *T* in horizons *A* and *B* and the decrease of *T* in horizon *C*, and, on the other hand examining the stability of *S* in the three horizons, we might explain the increase of the absorbed hydrogen in the surface and transition horizons, as before, by the hydrolyzing of the silicates, and the increase of the absorptive complex. Since in this case the calcium carbonate was entirely deficient, the protective and saturating effect was lacking also. This might be responsible for the differences between the chernozem soil previously treated and the present one. The exchangeable cations are still stable in the complex as shown by the data

TABLE 21.—Relation of exchangeable cations to total absorption capacity; Pusztakamarás soil

Horizon	*T*	Mg. equivalents of exchangeable cations as per cents of total absorption capacity (*T*)					*S*	*V*
		Ca	Mg	K	Na	H		
	mg. equiv.						mg. equiv.	
A	45.3	43.2	3.1	2.6	1.8	49.3	23.0	50.7
B	48.3	40.8	3.1	2.9	1.8	51.4	23.5	48.6
C	37.1	50.4	3.0	3.0	3.7	39.9	22.3	60.1

in Table 22. This might indicate again that the neutral medium prevailing in chernozem soil does not materially leach out any calcium from the complex even in the absence of calcium carbonate. This is a striking difference from acid soils, where we have found considerable washing out of exchangeable calcium.

TABLE 22.—Exchangeable cations of the three horizons of the Pusztakamarás soil

	Horizon	Ca	Mg	K	Na	Total = *S*
Exchangeable cations in mg. equiv.	*A*	19.6	1.4	1.2	0.8	23.0
	B	19.7	1.5	1.4	0.9	23.5
	C	18.7	1.1	1.1	1.4	22.3
Exchangeable cations in % of the total (*S*)	*A*	85.2	6.1	5.2	3.5	100
	B	83.9	6.4	5.9	3.8	100
	C	83.9	4.9	4.9	6.3	100

These data are in full agreement with the theory and the experiments of Gedroiz on chernozem soils. We might conclude consequently, that under the conditions of soil-formation in which the chernozem soils might develop the soil-leaching is restricted to the washing out of water-soluble (chiefly sodium) and, more or less, alkaline earth carbonates if present. In the absorptive complex the calcium cation is by far the most dominant. Nevertheless in the present soil the acid-decomposable magnesium silicates are in excess of those of calcium. The alkali cations do not play any marked rôle in the absorptive complex, in contradistinction to the alkali soil, as will be seen later on.

Finally in Table 23 we may get an idea of the distribution of the exchangeable cations in the total decomposed by concentrated hydrochloric acid.

It is very instructive to see that as a whole more than 70 per cent of the total calcium is exchangeable whereas other cations are far less exchange-

TABLE 23.—Distribution of exchangeable cations in the total dissolved by concentrated hydrochloric acid; Pusztakamarás soil

Cation	Horizon	Total dissolved by concd. HCl	Exchangeable	Exchangeable as per cent of total cations dissolved by concd. HCl
		mg. equiv.	mg. equiv.	
	A	27.1	9.6	72.3
Ca	*B*	28.6	19.7	69.0
	C	22.5	18.7	83.0
	A	50.0	1.4	2.8
Mg	*B*	61.4	1.5	2.45
	C	74.8	2.45	1.47
	A	13.2	0.8	6.1
Na	*B*	10.0	0.9	9.0
	C	9.7	1.4	14.4
	A	25.4	1.2	4.72
K	*B*	26.4	1.4	5.3
	C	22.8	1.1	4.82

able. This fact might be explained by the following considerations: The calcium-aluminum silicates are as a rule (as in the case of Anorthite) much more likely to decompose by soil weathering than the alkali feldspars and other alkali silicates. The magnesium silicates are again more resistant in most cases. Consequently by soil weathering and the soil water saturated with carbonic acid, principally calcium bicarbonate solution infiltrated the soil horizons, with insignificant admixture of magnesium, potassium and sodium salts. As the energy of absorption of the calcium cation is relatively greater, according to Gedroiz, than that of the other three and especially that of the alkali cations, the calcium cation concentration in the soil solution prevalent was not only in excess in the solution itself, but was able also to displace the other cations of the absorptive complex, originally present in the soil. However it was not strong enough to displace the absorbed hydrogen by the supposed hydration and hydrolyzing of the weakened silicates.

In conclusion now, we are entitled to define the soil-leaching in neutral medium in the sense, that in the prevailing soil-solutions the calcium cation is relatively dominant among the cations, whereas among the anions it is the bicarbonate.

Soil-Leaching in So-Called Alkali Medium

At first I should like to point out that the term "alkali-medium" does not mean in every case a soil with alkaline reaction, that is the pH value

of which runs over 7, because as we have seen above, the reaction of the so-called neutral soils reaches very often a pH of 8, if calcium carbonate is present in abundance. On the other hand, we have numerous instances where the alkali soil has a reaction under pH 7, and still we have to do with a typical alkali soil, and all genetic factors prove that the formation of this type of soils is the result of the reaction of the absorbing complex and alkali-salt solutions in the soil. In our country a considerable part of the so-called "Szik" land belongs to this type of alkali soil.

The Russian "Soloti" soils are, according to Gedroiz (3, p. 13), a secondary type of soils resulting from the hydrolyzing process of the absorbing complex of the solonetz, saturated originally to a high degree with sodium cation. I do not want to discuss this question of soil classification here, but I simply emphasize that this secondary type of alkali soil has its origin also in a medium where alkali salts were originally dominant.

In my paper "Contribution to the Theory of the Origin of Alkali Soils" (21), I have shown that the relative distribution of exchangeable cations in the absorptive complex is responsible for the characterization of the alkali soils. But at this time I had no reliable data as regards the degree of saturation of these soils. In the following I will give an example of that.

The soil we have investigated is again from the large alkali fields of Hortobágy, but represents a typical solonetz structure. The top-horizon, A, 0 to 9 cm. deep, is a compact ash-gray eluvial layer, which covers the upper part of the illuvial horizon, B_1, with a typical columnar structure, about 9 to 29 cm. deep, and dark brown in color. This is followed by the middle of the illuvial horizon B_2, with a prismatic structure, 29 to 55 cm. deep, and similarly dark brown in color. Then we have the lower part of the illuvial horizon, B_3, with gradual transition to the original regolite, a loess-like yellow clay rich in calcium carbonate the upper part of which, C_1, is still high in calcium carbonate and 70 to 100 cm. deep. The next horizon, C_2, is the richest in calcium carbonate and 100 to 125 cm. deep. This is underlain by a similar horizon, C_3, 125 to 137 cm. deep, but somewhat re-colored by iron oxide. The subsoil on which the above soil-profile has been developed is a blue-gray, impervious, clay, horizon D, sampled 137 to 150 cm. deep. The whole is a typical profile for the most of our compact Szik soils in the Tisza River valley. The chemical composition of the concentrated hydrochloric acid extract is given in Tables 24 and 25.

I do not intend here to enter deeper into the discussion of the above figures; I will simply draw my conclusions in regard to the soil-leaching process. First we have evidence which indicates that the horizon A is really an eluvial horizon and horizons B_1, B_2 and B_3 are illuvial products.

The accumulation of the cations in horizons B_2 and B_3 is responsible for that conclusion. This leaching down of the cations was partly chemical, partly mechanical, as in the case of acid soil-leaching. Nevertheless if

TABLE 24.—Chemical composition of hydrochloric acid extract of profile of Hortobágy alkali soil; expressed as per cent of dry soil

	Horizon							
	A	*B_1*	*B_2*	*B_3*	*C_1*	*C_2*	*C_3*	*D*
Na_2O	0.90	2.32	*3.00*	1.96	0.78	0.81	0.67	0.89
K_2O	0.36	0.43	0.55	*0.70*	0.27	0.29	0.26	0.29
CaO	0.63	0.77	1.09	0.69	10.26	*16.00*	14.53	14.40
MgO	0.27	0.70	0.67	*1.65*	1.42	0.23	0.24	0.35
MnO					0.02	0.98	*1.04*	0.78
Al_2O_3	3.60	5.77	8.15	8.33	6.65	6.63	*8.95*	8.25
Fe_2O_3	0.57	3.32	6.81	*7.00*	4.14	3.60	4.63	4.50
SO_3	0.18	0.26	*0.58*	0.46	0.01	0.23	0.27	0.17
P_2O_5	0.21	0.13	0.12	0.20	0.15	0.07	0.05	0.04
CO_2					7.20	*11.55*	10.62	10.45
SiO_2 soluble in concd. HCl and 5% KOH	5.83	10.88	20.75	*21.20*	12.94	12.75	13.50	13.36
Loss on ignition	*10.90*	2.02	2.24	2.25	1.96	1.46	1.61	2.15
Insoluble residue	*76.50*	73.75	55.75	55.15	54.80	46.00	44.00	44.95
Total	99.95	100.35	99.71	99.59	100.60	100.60	100.37	100.59

we compare the respective figures, we might see at once a characteristic difference. In the case of the acid soil-profile, the sodium plays an insignificant rôle and is more or less likely to be washed down. In the alkali soil-profile, on the contrary, we notice a concentration towards the sur-

TABLE 25.—Milligram equivalents of ions in the hydrochloric acid extract of the Hortobágy alkali soil; calculated as per cents of total milligram equivalents

		Horizon							
		A	*B_1*	*B_2*	*B_3*	*C_1*	*C_2*	*C_3*	*D*
Total cations, in mg. equivalents		306.1	607.9	916.7	940.1	1008.4	1159.9	1283.4	1234.7
Equivalent per cent of the total	Na^{I}	9.5	12.24	10.56	6.74	2.50	2.22	1.68	2.35
	K^{I}	2.5	1.53	1.30	1.58	0.57	0.55	0.43	0.49
	Ca^{II}	7.3	4.60	4.24	2.65	36.08	48.93	40.45	41.38
	Mg^{II}	4.4	5.70	3.63	8.95	6.95	4.94	0.95	1.48
	Mn^{II}					0.05	2.38	2.29	1.76
	Fe^{III}	7.0	20.44	27.92	28.05	15.35	11.59	13.43	13.60
	Al^{III}	69.3	55.48	52.35	52.00	38.50	33.39	40.77	38.84
	SO_4^{II}	1.5	1.06	1.58	1.22	0.02	0.49	0.52	0.32
	$P_2O_5^{III}$	3.5	0.90	0.55	0.90	0.63	0.25	0.16	0.14
	CO_3^{II}					32.33	45.03	37.37	38.24
	SiO_4^{IV}	95.00	98.04	97.87	97.88	67.02	54.23	61.95	61.30
Surplus SiO_2		1.47	1.83	7.32	7.33	2.66	3.21	1.42	1.87

face. The leaching down of iron and aluminum is concordant with that in acid soils. Again I could not detect any striking difference in respect to the amount or ratio of silica or alumina directly soluble in 5 per cent potassium hydroxide as Gedroiz emphasizes in his paper cited above (3, p. 22). The data we have obtained are as follows:

TABLE 26.—Silica and alumina dissolved by 5 per cent potassium hydroxide; Hortobágy alkali soil

Expressed as per cent of dried soil

	Horizon							
	A	B_1	B_2	B_3	C_1	C_2	C_3	D
SiO_2	1.54	1.70	1.87	2.04	1.51	1.49	1.55	1.58
Al_2O_3	0.54	0.58	0.35	0.32	0.50	0.48	0.45	0.44

We might notice a slight tendency toward the accumulation of alkali-soluble silica in horizon B_3, and a gradual decrease of alumina soluble in alkali, a fact just opposite to the evidence of Gedroiz. It may be that the solotization in our case was not advanced as far as in the example cited by him.

The salt content of the single horizons is recorded in Table 27.

TABLE 27.—Salt content and organic matter of Hortobágy alkali soil

Horizon	Per cent content of air-dry soil in		Per cent of organic matter $CO_2 \times 0.471$ in dried matter at 100° C.
	Total salts	Na_2CO_3	
A	0.0 -0.1		8.52
B_1	0.1 -0.2		2.78 (?)
B_2	0.3 -0.4		1.74
B_3	0.4	trace	1.27
C_1	0.25-0.30	0.14	0.49
C_2	0.20-0.25	0.17	0.23
C_3	0.20-0.25	0.20	Not determined
D	0.20-0.25	0.09	Do

The total salt content was determined by using a 1:5 ratio of soil: water, according to Dr. G. Schay (17) and proves that the salt content in the upper horizon is low enough to indicate the possibility of solotization. The organic matter is somewhat in contradiction to this supposition because if we admit a washing down of alkali cations, we are forced to assume the leaching out of humus from the surface horizon. The high figures for the organic matter (determined by dry combustion according to Albert and Bogg (1)), in correspondence with the high value of the loss on ignition in Table 24, prove incontestably the presence of a large quantity of organic matter, 4 to 5 times as much as in horizon B_1. The contradiction in the latter case between the organic matter content and the loss on ignition could not be explained but the differences from the corresponding values for horizon A are so large that we do not commit any error in estab-

lishing the fact that the surface horizon, though lighter in color contains more organic matter than the B_1-horizon. Nevertheless the darker color of the latter permits the assumption that the high organic content of horizon A is in the main to be attributed to undecomposed plant debris so fine, that it was impossible to separate them by sieving. On the other hand the mobilizing of the darker humus solution from the surface horizon A, to B_1 and B_2 is at the same time still possible. Further investigation in this direction is in progress and may be reported later on. Now in regard to the exchangeable cations, we find the respective figures in Tables 28 and 29.

TABLE 28.—Exchangeable cations in the hydrochloric acid extract of the Hortolágy alkali soil

Horizon	Milligram equivalents in 100 g. dried soil				
	Ca	Mg	K	Na	Total = S
A	6.2	5.5	1.2	7.7	20.6
B_1	9.6	6.2	1.0	14.6	31.4
B_2	10.3	7.3	0.9	23.8	42.3
B_3	9.9	9.5	1.0	20.5	40.9
C_1	14.4	8.8	1.8	14.6	39.6
C_2	15.5	8.6	2.9	12.4	39.1
C_3	16.1	8.0	2.4	14.0	40.5
D	15.9	8.4	2.0	12.8	39.1

TABLE 29.—Milligram equivalents of exchangeable cations, expressed as per cent of the total exchangeable (S); Hortolágy alkali soil

Horizon	Ca	Mg	K	Na
A	30.1	26.7	5.8	37.4
B_1	30.6	19.7	3.2	46.5
B_2	24.4	17.2	2.1	56.3
B_3	24.2	23.2	2.4	50.2
C_1	36.4	22.2	4.5	36.9
C_2	38.9	22.0	7.4	31.7
C_3	39.8	19.7	5.9	34.6
D	40.6	21.5	5.1	32.8

It is evident from the data of Tables 28 and 29 that the dominant rôle of sodium in the absorbing complex is again demonstrated, as myself and other investigators have proved in numerous cases for alkali soils. It is instructive to see how the protective effect of the calcium carbonate present influences the decrease of sodium in the complex, starting with horizon C_1.

Now in Table 30 we have a résumé of the chemical character of the absorbing complex *T*.

TABLE 30.—Relation of exchangeable cations to total absorption capacity; Hortobágy alkali soil

Horizon	*T*	Mg. equivalents of exchangeable cations, as per cent of total absorption capacity (*T*)					*S*	*V*
		Ca	Mg	K	Na	H		
A	36.8	16.8	15.0	3.2	20.9	44.1	20.6	55.9
B_1	36.8	26.1	16.8	2.7	39.7	14.7	31.4	85.3
B_2	47.4	21.8	15.5	1.9	50.2	10.6	42.3	89.4
B_3	45.8	21.6	20.7	2.1	44.6	11.0	40.9	89.0
C_1	44.4	32.4	19.8	4.1	32.9	10.8	39.6	89.2
C_2	43.8	34.6	19.6	6.6	28.4	10.8	39.1	89.2
C_3	45.0	35.8	17.8	5.4	31.0	10.0	40.5	90.0
D	45.6	34.9	18.4	4.4	28.1	14.2	39.1	85.8

We see that the *T*-complex increases with the *S*-value, and with depth the per cent of hydrogen absorbed is significant in horizon *A* but falls very quickly. However it does not disappear completely. This might be the influence of the beginning solotization.

In correspondence with this the reaction of the horizon *A* is slightly acid as shown in Table 31 and confirmed by the degree of saturation, $V=55.9$. The saturation of the lower horizons is far higher though not complete.

TABLE 31.—Acidity of the profile of the Hortobágy alkali soil

Horizon	pH of suspension		Titration acidity		H absorbed in *T* (*T*-*S*)
	In water	In *N* KCl	According to Daikuhara-Kappen with *N* KCl	With sodium acetate	
					per cent
A	5.8	4.4	2.2	21.7	16.2
B_1	6.5	6.3	1.5	2.2	5.4
B_2	7.4	7.12	0.1	0.5	5.1
B_3	7.6	7.21	0.1	0.3	4.9
C_1	8.5	7.88	0.15	0.15	4.8
C_2	8.7	7.16	0.10	0.2	4.7
C_3	8.9	7.79	0.15	0.15	4.5
D	8.9	7.42	0.17	0.2	6.5

Here we have a striking example of the fact that an alkali soil, if unsaturated, may have an acid reaction, though in the absorbing complex

we have considerable (20.9) sodium cations, but at the same time 44.1 per cent hydrogen. The result will be that the ratio between the hydrogen and hydroxyl ions in water suspension will give an equilibrium of an acid pH value, and with normal potassium chloride this acidity will increase, even more so with sodium acetate.

Finally in Table 32 we have the figures illustrating the relative values of exchangeable cations in per cents of the total acid-soluble cations. In the case of horizons C_1, C_2, C_3 and D we have subtracted the calcium equivalents corresponding to the carbonates present.

TABLE 32.—Relation of exchangeable cations to total acid-soluble cations; Hortobágy soil

Expressed as milligram equivalents per 100 g. dry soil

		Horizon							
		A	B_1	B_2	B_3	C_1	C_2	C_3	*D*
Ca	HCl-soluble	22.5	28.0	38.9	25.0	39.2	46.4	36.0	40.3
	Exchangeable	6.2	9.6	10.3	9.9	14.4	15.2	16.1	15.9
	Per cent exchangeable	27.55	34.2	26.5	39.4	36.7	32.78	44.69	39.45
Mg	HCl-soluble	13.5	34.6	33.3	84.5	69.6	10.9	12.2	18.3
	Exchangeable	5.5	6.2	7.3	9.5	8.8	8.6	8.0	8.4
	Per cent exchangeable	40.7	17.9	21.9	11.5	12.65	79.0	65.5	45.9
Na	HCl-soluble	29.0	73.4	96.7	63.5	25.0	25.8	21.6	29.0
	Exchangeable	7.7	14.6	23.8	20.5	14.6	12.4	14.0	12.8
	Per cent exchangeable	26.55	19.9	24.8	32.3	58.4	48.1	64.8	44.2
K	HCl-soluble	7.7	9.3	11.9	14.9	5.7	6.4	5.5	6.05
	Exchangeable	1.2	1.0	0.9	1.0	1.8	2.9	2.4	2.0
	Per cent exchangeable	15.6	10.8	7.55	6.7	31.6	45.3	43.6	33.1

If we compare these figures with the respective values of the acid (Table 5) and neutral soil (Table 16) we might note that, on the whole, in the alkali soil the exchangeable fraction represents a more considerable portion of the total cations, especially the alkali cations (Na and K).

I do not intend to enlarge this paper by citing other similar evidence in order to draw general conclusions in regard to the alkalization and solotization of the soils in an alkali medium. The available data are not sufficient for generalizing. I simply refer to my previous paper: "Contribution to the Theory of the Origin of Alkali Soils" (21) as well as to my monograph on "Hungarian Alkali Soils" (19) and studies on the

importance of the zeolite-humus-complex in the soil and on the soil reaction (22). Furthermore I quote the respective papers of Kelley (13), Gedroiz (6), and Arany (2). We might conclude still that the soil-leaching in alkali medium is characterized by two distinct phases: the alkalization of the soil, and the solotization of the alkali soil. The first is a base-exchange process, in which the alkali salt solution of relatively high concentration reacts on the zeolite-humus complex. The alkali cations gradually displace the other cations, especially the calcium cation, which is as a rule in abundance in the normal absorbing complex. The evidence of Kelley (13) proves that, in some cases, this exchange can go so far that the bivalent cations are entirely deficient in the absorbing complex. In my investigation I could not find a similar extremity with Hungarian "Szik" soils, which fact may be associated with the different type of climatic factors of the American arid and the Hungarian semi-arid climate. As a result of this base-exchange we have to do with a real soil-leaching, as the exchanged cations going into solution are washed down into deeper horizons. This results in the accumulation of calcium sulfate and calcium carbonate in the *C*-horizon.

The secondary process, that in our country very often followed the alkalization, is the solotization, as Gedroiz called this process, which consists in a gradual hydrolysis of the absorbing complex partly or fully saturated with alkali cations. This process will start as soon as the alkali salt concentration has diminished so far that the concentration of alkali cations in solution is not high enough to suppress the dissociation of alkali cations absorbed in the zeolite-humus complex. This is the reason that, in the case of soloti soils, or our so-called productive "Szik" soil, which are, at least in the horizons near the surface, poor in alkali salts (the total salt content of the dry soil ranges from about 0.05 to 0.20 per cent) the absorbing complex will be more or less unsaturated, that is, hydrogen ions will enter in the place of alkali cations. The above-treated alkali soil is an example of this kind of soil-leaching. This solotization is partly combined with or followed by the decomposition of the zeolite complex, resulting in free silica and alumina colloids, the quantity of which was not very considerable in the above-treated alkali soil. But Gedroiz has quoted more advanced instances.

Conclusions

I am far from drawing general conclusions in regard to the different soil-leaching processes from the very interesting results treated above. The amount and the variety of the investigated material are not sufficient for that. But we might nevertheless conclude:

(1) that on the basis of the detailed chemical analysis of the soil profiles we get very instructive illustrations in regard to the soil leaching process;

(2) that for this purpose not only the concentrated hydrochloric acid extract but the total analysis of the absorbed cations and hydrogen are sometimes very characteristic. Out of these results we could get characteristic differences between the three typical soil leaching processes. We have seen notably that in acid medium chiefly the calcium and sodium, in alkali medium only the calcium, of the absorbing complex are washed down, whereas in neutral medium the calcium alone is predominantly accumulated and protected against washing out. This is a provisional statement, supported by theoretical arguments, and very promising for enlarged and cooperative investigations.

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LAND UTILIZATION IN THE UNITED STATES

Dr. O. E. Baker, United States Department of Agriculture, reviewed the trend of land utilization in this country.

THE TREND OF LAND UTILIZATION IN THE UNITED STATES AND THE PRESENT SITUATION

DR. O. E. BAKER

INTRODUCTION

Many of you are starting next week on a swing around the circle of the United States and Canada, visiting several of our most important agricultural regions. While thinking how I could be of help to you in studying American soils and agriculture on this trip, it occurred to me that you might like to have in mind a few facts relating to land utilization that stand out prominently when one reviews the history of agricultural development in the United States, and would also be glad to have a brief summary of the present situation.

THE PROGRESS OF AGRICULTURAL SETTLEMENT WAS FROM POOR TO GOOD SOILS

The first fact to which I would call your attention is that agriculture in America up till near the beginning of the Twentieth Century expanded from poor to fair soils, then to good soils, and, finally, to excellent soils. As settlement advanced westward better and better land, speaking broadly, was brought into cultivation.

The first settlements along the Atlantic Coast were made, with two or three exceptions, in districts of poor soils,—sandy soils mostly, developed in a region of moderately heavy rainfall and consequently leached of much of the little lime and potash that they originally possessed. Many of our colonial farmers had a hard time making a living along this Atlantic Coast. In some colonies the cattle starved to death by the thousands in the winters, and sometimes the colonists almost starved too.

But during a century and a half of struggle, the pioneer farmers slowly forced their way inland from the coast, mostly up the rivers, and about the time of the Declaration of Independence, in 1775, agriculture was developing rapidly over this Piedmont region to the west of Washington, Philadelphia and New York, where the rainfall was a little lighter and the soils heavier and more fertile. Indeed, before this time settlement had advanced down the Shenandoah Valley, which you visited yesterday, where the rainfall is still lighter and the limestone soils are still more fertile than those of the Piedmont.

After the American people achieved independence, agricultural expansion was more rapid than ever. Population was doubling every 20 to 25 years,—possibly the rate of increase of population in America at this time was the most rapid in the history of the world. Moreover, it was owing very largely to natural increase—not to immigration. No sooner were the fathers settled in these Appalachian valleys than the children burst over or through the mountain barriers and moved on like an advancing army into the fertile lands of the Mississippi Valley. First, the rather infertile upper Ohio Valley and the rich limestone, Blue Grass region of Kentucky were occupied, and then the more accessible lands along the lower Ohio, the Mississippi and the lower Missouri rivers.

Up to the time of building the railroads the fertility of the soil was not the principal factor that determined the direction of settlement, except locally. The Ohio Valley was occupied long before the richer but less accessible lands in northern Ohio, Indiana and Illinois. Three factors other than soil fertility seem to have been especially important—(1) accessible location, especially with reference to the rivers, (2) wood and water for household use and for the stock, (3) peace and protection, especially from the Indians.

Before 1850, or about 75 years after the Declaration of Independence, the prairies were reached. Here the advance of settlement was somewhat retarded for a few years. Our early pioneers were forest dwellers and had hewn their farms out of one of the largest and densest forests, mostly of hardwoods, in the world. The prairie was something new and the settlers had to learn how to conquer it for agriculture.

Old men in Illinois, Wisconsin and Manitoba have told me that they were warned not to go out onto the prairie for the strong winter winds, the "blizzards," they were told, would blow down their houses, or the prairie fires of summer would burn them up. These prairie fires were a real menace, but more important were three other factors: (1) there was no firewood on the prairies to cook with and to burn in winter, (2) there were few springs of water on the prairies with which to water the stock, (3) there were fewer navigable streams in the prairie regions than in the forest lands to bear the grain and meat animals to market.

Just at this time, when the settlers were emerging from the eastern

forest lands and facing the western prairies three great inventions were developed: (1) well drilling machinery, which brought water to the springless and almost streamless prairies and plains; (2) railroads, which carried the pioneer's grain and cattle to market and brought in return coal and clothing; (3) grain harvesting machinery, which enabled one man to do the work of four and, with the gradual introduction of other machinery, has permitted the other three to live in the cities and develop industry and commerce. The period from about 1850 to 1900 was characterized by the exploitation of the prairies. These rapidly became the great granary of the nation, and supplied not only the United States, but also portions of western Europe with wheat and meat. During this half century nearly three times as much land was brought into agricultural use as during the two centuries preceding. And it was for the most part good land. More than half of our food supply now comes from these fertile prairies and plains of the Central West.

This fact, that the most fertile soils of the United States were in the center of the continent and were occupied only during the latter half of the nineteenth century, has had important economic and political consequences. It has meant that instead of agriculture occupying first the best and then advancing onto progressively poorer soils, with a consequent rise in the rental value of the land, and in the wealth of the old land owners, as pointed out more than a century ago by Ricardo, agriculture in America, speaking broadly, began on poor soils, then spread to fair soils, later to good soils, and, finally, onto excellent soils. This advance onto progressively better soils was an important factor in preventing the accumulation of rural wealth in the East, and, gradually, during the years that culminated in the Civil War, tended to impoverish the landed aristocracy that had developed in the "Old South." The advance from poor soils to good has probably made for democracy. You will find that American farmers almost everywhere are a very democratic people.

This progress from poor to good land has also promoted the development of industry by providing cheap food. You will find that even today the cost of food is much less in the prairie regions than here in the East. And I may add that industry appears to be slowly expanding into the regions of fertile land and cheap food,—note the rise of the automobile industry in Michigan, Indiana and Wisconsin.

Since 1900 the Progress of Settlement Has Been from Good to Poor Land

The second outstanding fact that I wish to bring to your attention is that about the year 1900 American agriculture, indeed our entire national culture, reached thė turning point in its history. Practically all the good land had been brought into use for crops. Settlement had now advanced across the Black Earth (Chernozem) belt that extends from west-central

Texas to eastern North Dakota, and was pressing onto the semi-arid, chestnut-brown soils that lay beyond. By 1910 the best of these brown soils had been broken for dry-land crops, and before 1920 much semi-arid short grass land had been plowed and seeded to grain which it would have been better never to have plowed. Between 1900 and 1920 improved land increased by nearly 100 million acres, or almost a fourth; but the progress of settlement was from excellent land to good land, from good land to fair land, and, finally, onto poor land.

Since 1920 Agricultural Settlement Has Stopped

The third fact that I hope you will remember on this trip is, that that magnificent episode, the agricultural conquest of the North American continent, is practically over. The cycle is almost complete. By 1920 the land that was being broken for crops was but little better than that first settled by the early colonists along the Atlantic Coast. The country has been settled,—practically all the land that does not involve unprofitable expense for clearing or reclamation has been brought under cultivation. Much land remains potentially available for crop production,—almost as large an area, in fact, as that which has been put into crops. But it is land that is too wet or too dry, too steep or stony or infertile to justify its use or reclamation at present prices of farm products, or such prices as may be expected for several years to come.

What does the exhaustion of the supply of good and even fair land mean? Does it mean that the farmers of the United States must continue to advance onto poorer and poorer soils, that rents of the good lands will rise, that tenancy will increase, that the rich will become richer and the poor poorer, and the general welfare will decline?

On the contrary, so far as concerns the immediate past and the prospect for the next decade, agriculture has not advanced since 1920 onto poorer soils; instead, the agricultural area has contracted since the World War, and land values are lower than they were in 1910. Farmers as a class have not prospered in the past seven years, while the welfare of the urban population has advanced more rapidly than ever before. American agriculture has experienced the most severe depression in its history, while city industries as a whole have enjoyed a most prosperous period.

Between 1919 and 1924 the Census shows a decrease in farm land, and also in crop acreage, for the first time in the history of our nation. The Census shows also a decrease of pasture land in farms, in number of horses and mules (considered jointly), of cattle and of hogs on farms. The Census shows, furthermore, a decrease in number of farms, of farm population and of number of persons engaged in agriculture.

The Increase in Agricultural Production

The fourth fact which it will be helpful for you to keep in mind is that since the World War there has occurred a most notable increase in agricultural production in the United States. One would expect a decrease but, instead, agricultural production during the past five years, as compared with the five years preceding, is about 14 per cent larger. This is a 60 per cent greater increase in agricultural production than in population. Indeed, the increase in agricultural production since the war has been more rapid, apparently, than in any previous period since 1900 and probably since 1870. With crop land showing an appreciable decrease, with pasture land in farms decreasing, with live stock less numerous than at any time during the past forty years, with farm population declining, even the prices of farm products showing a notable depression, how could agricultural production increase so greatly?

Manifestly some less clearly recognized factors have come into play. It is evident that there are other means of increasing agricultural production than by expansion of the crop area or increase in the amount of labor applied to the land. In order that the entire situation may be understood it is necessary to note also changes in consumption. The means of increasing the supply of agricultural products may be considered under three headings,—(1) changes in consumption by human beings, (2) changes in production of the crops and pastures, (3) changes in transformation of the crop and pasture production into animal products for human use.

(1) Changes in consumption may involve shifts from products that require more land to those that require less land to produce an equal value, or may involve shifts in exports and imports.

(a) Increased consumption of foods of vegetable origin and decreased consumption of foods of animal origin might increase the supply of agricultural products without increasing the crop acreage. The Chinese, for instance, are supporting nearly four times as many people as live in the United States on only about one-half as large area in crops, and the average acre yield of all the cereals except rice is lower in China than in the United States. But a statistical study has shown that the proportion of vegetable and of animal products in the diet of the American people, each group of products being combined on the basis of average farm price 1917–1926, was practically the same in the period of 1922–1926 as in the period 1917–1921. Nevertheless, there has been a much greater increase in production of animal products than of vegetable products (accompanied by a great increase in imports of vegetable products). Since animal products require much more land to produce a unit quantity of food than do vegetable products, it is evident that the effect of this greater increase in production of animal products than of vegetable products

would be to reduce agricultural production rather than increase it, in so far as the relative acreage in the respective classes of products is responsible for changes in aggregate production.

(b) The much larger increase in production of animal foods than of vegetable foods has been balanced by a great increase in imports and decrease in exports of vegetable foods. Our imports of sugar have almost doubled since the war and our exports of wheat have declined. We import now, mostly from Cuba and our tropical possessions, twice as much sugar as we export of wheat, measured by value. Production of food and fiber crops has increased about 14 per cent; consumption has increased about 18 per cent.

(2) Changes in crop and pasture production may be owing to a shift from the normally less productive use of land for pasture to the more productive use for crops, or to shifts from the less productive to more productive crops, or to higher yields per acre of the several crops or of the pastures.

(a) Agricultural production could be increased by a shift from pasturage to crop land. But, as already noted, crop land harvested in 1924 was about 13,000,000 acres less than in 1919, according to the Census, and in the period 1922–1926 was about the same as in the period 1917–1921, according to the estimates of the United States Department of Agriculture. About half of the 13,000,000 acres less crop land in 1924 than in 1919 was used for pasture, and half was allowed to lie idle. The decrease in crop land was about 3 per cent and the increase in pasturage, including that outside of farms, was about 2 per cent, measured in carrying capacity. A slight reduction in vegetable matter produced would be indicated by the Census figures and a stationary condition by the estimates of the United States Department of Agriculture. Clearly this factor cannot account for the increase in production of animal products.

(b) Agricultural production could be increased by a shift from less productive crops to more productive crops—oats to soy beans, for instance, or from wild hay to alfalfa. A statistical study indicates that such shifts since the war, mostly to more vegetables and fruits, account for one-fifth (1917–1921 compared with 1922–1926) to one-fourth (1919 compared with 1924) of the increase in agricultural production.

(c) Agricultural production could be increased, obviously, by higher crop yields per acre, without increasing the crop area. The statistical study shows, however, that this factor apparently accounts for less than a tenth of the increase in agricultural production. Taking all crops as a whole, acre yields have increased only one to two per cent. The farmers have been too poor to buy more fertilizer. That yields per acre have been maintained is owing largely to the after-effect of fertilizer applied and drainage ditches dug during the war years, when the high prices of farm products justified such expenditures.

(3) Changes in transformation of vegetable into animal products account, apparently, for about 70 per cent of the increase in agricultural production. This increase could be and has been achieved in three ways.

(a) Agricultural production could be increased by shifts from the less productive classes of farm animals to the more productive per unit of feed consumed,—beef cattle to dairy cattle or hogs, for instance. Such a shift has been in progress, and it accounts, apparently, for one-tenth to one-fifth of the increase in production of animal products. The wide difference between a tenth and a fifth is owing to differences in estimates of number of livestock as given by the two major statistical sources used. The better figures, indicate the higher proportion. Accepting 20 per cent as the figure and recalling that the increase in animal products constituted 14 per cent of the total increase in agricultural production, it appears that this factor accounts for about one-seventh of the increase in agricultural production during the 5 years.

(b) Agricultural products available for human consumption have been increased by the replacement of horses and mules, by tractors, trucks and automobiles. The decrease in horses and mules between 1919 and 1924 released about 9,500,000 acres of crop land formerly required to feed these work animals. These 9,500,000 acres constitute about 33 per cent of the 28,700,000 acres that would have been required to produce the 17.2 per cent aggregate increase in animal products. Applying this 33 per cent to the 70 per cent which the increase in animal products constitutes of the total increase in agricultural production, the figure of 28 per cent is obtained as a measure of the contribution of this shift from animal to mechanical power on farms and in cities to the total increase of agricultural products. Since 1924 the decrease in horses and mules has continued at a rapid rate so that it is probable this factor now accounts for over a fourth of the increase in agricultural production since the war.

(c) Agricultural production could be increased by the production within each class of farm animals of more meat (or milk) per unit of feed consumed. This, apparently, has been an equally important factor in causing the increase in production. It has proven easier and cheaper to send the "boarder" cow to the "block," to lower the losses from hog cholera, to raise 5 pigs per litter instead of 4 by keeping the pens cleaner and by other methods, to ship beef cattle to market when one or two years old instead of when three or four years old, as was formerly common practice, than it has to buy fertilizer and increase the acre yields of the crops.

Production per animal is a different matter than production per unit of food consumed, nevertheless, it is interesting to note that dairy cows have increased only slightly in number (not at all, if the Census figures may be accepted), but milk production has increased probably 20 per cent, perhaps 25 per cent, since the World War. Beef cattle (total cattle less

dairy cows and heifers) decreased 7 per cent between 1919 and 1924, according to the Census, and 13 per cent between the 5-year periods 1917–1921 and 1922–1926, according to the estimates of the United States Department of Agriculture; but the production of beef and veal increased 6 or 7 per cent. Much of this increase, however, was owing to depletions of stock on farms. Hogs decreased 1 per cent between the 5-year periods 1917–1921 and 1922–1926, but the production of pork and lard increased about 18 per cent. The number of sheep and lambs decreased 2 per cent between the periods 1917–1921 and 1922–1926 but the production of mutton had increased 8 per cent. The number of chickens on farms was 13.8 per cent greater on Jan. 1, 1925 than on Jan. 1, 1926 but the production of chickens was 15 per cent greater in 1924 than in 1919, according to the Census, and of eggs was 16 per cent greater.

Total foods of animal origin increased about 17 per cent between the period 1917–1921 and the period 1922–1926, but no more feed for farm animals was available in the latter period than in the former. Subtracting the contribution of the shift from less productive to more productive classes of livestock, and the contribution caused by the substitution of automobiles and tractors for horses and mules, it appears that about 47 per cent of this increase in animal products, or nearly a third of the total increase in agricultural production between the periods 1917–1921 and 1922–1926, may be assigned to this increasing production of meat, milk and wool per unit of feed consumed. This indicated increase in efficiency of farm animals in transforming stock feed into human food, is about 8 per cent, or fully one and a half per cent a year. This is independent of the shift from the less productive to the more productive classes of farm animals.

Adding the 3.4 per cent increase in production of food of animal origin assignable to the shift from the less productive toward the more productive classes of farm animals per unit of feed consumed (beef cattle to dairy cattle and hogs), to the increase of 8.1 per cent in production assignable to the increased efficiency of the several classes of farm animal in transforming food into feed, there is indicated an increase of over 11 per cent in the five years in the production of animal foods per unit of feed consumed. Without any increase in feed consumed, the milk and meat animals in the United States have produced, apparently, an increase in animal foodstuffs since the World War considerably greater than the increase in human population.

It appears, therefore, that expansion of the agricultural area, which has heretofore been the chief cause of the increase in agricultural production, has since the World War ceased to be a factor; and that increase in crop yields per acre cannot account for more than a small fraction of the unprecedented increase in agricultural production. Practically all of the increase, in other words, is owing to other than soil factors.

The Prospect

Although it is true that ultimately all agricultural production comes from the soil and the sunshine, a great increase in efficiency of transformation of vegetable matter for human use has been and undoubtedly will continue to be made. It seems probable that the total crop acreage in the United States will not increase greatly for another decade, possibly not increase at all, and that a notable increase in crop yields per acre cannot be expected for several years either. Prices of farm products are too low in most parts of the United States and seem likely to remain too low for several years, unless an unfavorable season interrupts, to justify increased expenditure for fertilizer and other soil improvements. The efforts of the farmers will be directed to producing more per man rather than more per acre.

The pressure of population on the land in the United States is being met, and it appears probable will continue to be met for several years, principally by the substitution of mechanical for animal power on farms and by improving the efficiency of meat and milk animals in transforming feed into food. These and the other means of increasing the supply of agricultural products have proven so effective that the greatest national problem at present is how to dispose of the agricultural surplus.

But both these means of increasing agricultural production obviously have a limit. We are raising annually only half as many horses as die. If this ratio continues the substitution of tractors and automobiles for horses and mules can last only a few decades, for then most of the horses will be dead.

The increasing efficiency of meat and milk animals must also reach a limit, but the attainment of that limit, at least for milk cows, is more remote. Nevertheless, it appears probable that, after a decade or two, American agriculture must fall back on the time-proven methods of increasing agricultural production by expanding the area of crop land and by securing higher yields per acre both of crops and of pastures.

PRODUCTIVE CAPACITY OF THE GLOBE

Dr. A. Penck, University of Berlin, Germany treated the march of civilization as effected by world crops.

DAS HAUPTPROBLEM DER PHYSISCHEN ANTHROPOGEOGRAPHIE [1]

Dr. A. Penck

Friedrich Ratzel hat 1882 durch Herausgabe des ersten Bandes seiner Anthropogeographie der Pflege der Geographie des Menschen einen so

[1] Reprinted from Sitzungs berichte der pressischen Akademie der Wissenchaften. Jahrgang. 1924. Physikalisch-Mathematische Klasse. S. 242.

starken Impuls gegeben, dass nicht nur der von ihm geprägte Ausdruck gang und gäbe geworden ist, sondern dass auch die Erörterung anthropogeographischer Probleme vielfach eingetreten ist. Was RATZEL unter der von ihm in den Vordergrund gerückten Disziplin verstand, brachte er im Untertitel des Werkes: "Grundzüge der Anwendung der Erdkunde auf die Geschichte" zum Ausdruck. Er stellte sich auf denselben Boden, den KARL RITTER einnahm, als dieser durch Sammlung seiner Akademie-Abhandlungen "zur Begründung einer mehr wissenschaftlichen Behandlung der Erdkunde" den Titel seiner allgemeinen Erdkunde "im Verhältnis zur Natur und zur Geschichte des Menschen" rechtfertigen wollte.[1] 1891 hat RATZEL sein Programm durch den zweiten Band seiner Anthropogeographie wesentlich bereichert, dem er den Untertitel "Die geographische Verbreitung des Menschen" gab. Spätere Auflagen haben hieran nichts gerüttelt; als 1899 der erste Band in einer gänzlich umgearbeiteten Auflage erschien, blieb er der Anwendung der Geographie auf die Geschichte gewidmet.

Die Untertitel von RATZELS Anthropogeographie kennzeichnen deren doppelte Zielsetzung. Aber der zweite Band trägt einen kaum weniger historischen Einschlag als der erste. Auch in der gegenwärtigen Verbreitung des Menschen erblickt RATZEL in erster Linie das Ergebnis einer geschichtlichen Entwicklung. Das geht so weit, dass er im Abschnitt "Spuren und Werke des Menschen auf der Erdoberfläche" nicht bloss die Städte als geschichtliche Mittelpunkte, sondern auch die Ruinen behandelt. Aber vergebens sucht man in diesem Abschnitte, der hauptsächlich den Wohnplätzen und Wegen des Menschen gewidmet ist, auch nur einen Hinweis auf die wichtigste Beeinflussung der Erdoberfläche durch den Menschen, nämlich auf die Schaffung des Kulturlandes, welches grossen Teilen der Erdoberfläche das eigenartige Gepräge aufdrückt. Zwar erwähnt RATZEL im Abschnitte "Über das statistische Bild der Menschheit" die Kulturlandschaft. Aber rasch geht er über sie weg; so sehr sieht er in ihr das Gewordene, dass er sie umfassender und treffender historische Landschaft nennen möchte. Nach ihm werden Beziehungen zwischen Wärme und Dichtigkeit der Bevölkerung zwar am wirksamsten durch die Bodenkultur vermittelt[2], aber an der fundamentalen Frage geht er vorüber, unter welchen natürlichen Voraussetzungen sich die Kulturlandschaft überhaupt entwickeln kann und welche Triebkräfte zu ihrer Entstehung führen. Gewiss, RATZEL kennt den Einfluss der Naturbedingungen auf die Menschheit. Er widmet ihm ein ganzes Kapitel in der ersten Auflage des ersten Bandes der Anthropogeographie. Hier spricht er von Wirkungen auf den Zustand, die durch Physiologie und Psychologie, und von Wirkungen auf die Handlungen, die vornehm-

[1] Einleitung zur allgemeinen vergleichenden Geographie und Abhandlungen zur Begründung einer mehr wissenschaftlichen Behandlung der Erdkunde. Berlin 1852.

[2] Anthropogeographie II, 1891, S. 181 und 261.

lich durch die Geschichte zu erforschen sind (S. 60). Aber von dem grossen Zwange, den seine eigene Natur auf den Menschen ausübt, sich zu ernähren, spricht er nicht. Nur ganz flüchtig streift er diesen wichtigsten Punkt in der zweiten Auflage (S. 69). Er erkennt zwar eine Fülle von Wirkungen in dem ersten und dringendsten Bedürfnis der Ernährung, tut jedoch den Gegenstand dann mit den Worten ab: "Man braucht, um das einzusehen, nicht mit LACOMBE eine théorie d'urgence." Auch in HETTNERS[1] anregendem Vortrage über die Geographie des Menschen wird hierauf kaum eingegangen. Gerade aber die Nahrungsfrage ist diejenige, welche Biogeographie und Anthropogeographie gemein haben und welche die festeste Anknüpfung der Anthropogeographie an die Physiogeographie ermöglicht. Sehr mit Recht schreibt RATZEL 1899[2]; "Die Anthropogeographie wird nicht eher auf eine feste wissenschaftliche Basis gestellt sein, als bis die allgemeinen Gesetze der Verbreitung alles Lebens auf der Erde die Ecksteine ihres Fundamentes bilden." Aber diese Ecksteine lässt er in seinem Gebäude aus. Die von ihm begründete Anthropogeographie bedarf noch eines wesentlichen Ausbaus nach der biologischen und physischen Seite hin; zur historischen Anthropogeographie müssen wir eine physische gesellen, in der die vitalen Fragen des Menschen zu ihrem Rechte kommen.

Ich will hier das Hauptproblem einer solchen physischen Anthropogeographie behandeln, nämlich die Beziehungen zwischen Erdoberfläche und Mensch, welche durch dessen Nahrungsbedürfnis hergestellt werden. Ich bediene mich zunächst, um den rein physikalischen Charakter der einschlägigen Untersuchungen auch äusserlich hervortreten zu lassen, der Sprache sehr einfacher mathematischer Formeln. Zwischen Nahrungsproduktion (N) und Zahl der Menschen auf der Erde (Z) besteht die Grundgleichung

$$N = Zn,$$

worin n das durchschnittliche Nahrungsbedürfnis des einzelnen bedeutet. Die gesamte Nahrungsproduktion aber ergibt sich aus der gesamten Nahrung liefernden Oberfläche (O) und der mittleren Produktion der Flächeneinheit (p); wir erhalten daher folgende wichtige Beziehung zwischen der Grösse der Erdoberfläche und der Zahl der Menschen:

$$Op = Zn.$$

Nun kommt von der gesamten Erdoberfläche O im wesentlichen nur die Landoberfläche L als Nahrungsmittellieferer in Betracht; unbeschadet der nicht geringen Bedeutung, welche Küsten- und Hochseefischerei für die Ernährung sehr vieler haben, dürfen wir bei einer ersten Näherungsrechnung statt O in unsere Formel L einsetzen und die Zahl der Menschen wie folgt ausdrücken:

$$Z = \frac{Lp}{n}.$$

[1] Geographische Zeitschrift XIII, 1907, S. 401.
[2] Anthropogeographie I, 2. Aufl. S. 9.

Es ist die Zahl der Menschen auf der Erde gleich der Landoberfläche multipliziert mit deren mittlerer Produktion auf der Flächeneinheit, dividiert durch das mittlere Nahrungsbedürfnis des einzelnen. Alle die letztgenannten Grössen sind endliche, und da das Nahrungsbedürfnis des Menschen nicht gleich Null werden kann, so ist die Zahl der Menschen auf der Erde beschränkt.

Die Produktion auf der Flächeneinheit ist eine Funktion der Produktionskraft von Klima und Bodenbeschaffenheit sowie der Intensität der Bodenkultur oder der Wirtschaft. Das Nahrungsbedürfnis n des Menschen wechselt von Ort zu Ort. Aber nach den Untersuchungen von RUBNER [1] schwankt es innerhalb ziemlich enger Grenzen, und es wechselt weniger die Summe des benötigten Eiweiss und Fettes sowie der benötigten Kalorien als die Zusammensetzung der Nahrung, welche diese Summe liefert. Diese Zusammensetzung zeigt bemerkenswerte örtliche Anpassungen: jedes Gebiet einer bestimmten Nahrungsproduktion hat eine charakteristische Nahrungskonsumption des einzelnen von ziemlich gleicher Grösse. Wir können daher die Zahl z der Menschen eines Gebietes l durch die Formel

$$z = \frac{lKi}{n}$$

ausdrücken, wenn K dessen durch die Kraft von Klima und Boden bedingte Höchstproduktion auf der Flächeneinheit ist, die durch die wechselnde Intensität i der Bodenkultur mehr oder weniger zur Geltung gebracht wird; K ist eine Quantität, i ist eine blosse Zahl. Die Bewohnerzahl eines Gebietes mit der Volksdichte d ergibt sich aber auch aus der Formel:

$$z = ld.$$

Nehmen wir nun an, das Gebiet sei ein geschlossenes Wirtschaftsgebiet, es exportiere und importiere nichts, so ergibt sich:

$$d = \frac{Ki}{n},$$

d. h. die Volksdichte eines sich selbst erhaltenden, Nahrung weder importierenden, noch exportierenden Gebietes ist gleich seiner Höchstproduktion nach Klima und Bodenbeschaffenheit auf der Flächeneinheit, nämlich seiner natürlichen Produktionskraft, multipliziert mit einem Faktor, der die Intensität der Bodennutzung darstellt (i), dividiert durch das Nahrungsbedürfnis des einzelnen. Solange wir dieses nun als in engen Grenzen schwankend ansehen dürfen, können wir die Volksdichte eines Gebietes proportional seiner natürlichen, durch Klima und Boden bestimmten Produktionskraft, multipliziert mit einem die Intensität des Bodenbaus wiedergebenden Faktor setzen. Letzterer ist ganz wesentlich

[1] Die kommende Friedensernährung. Zeitschr. f. ärztliche Fortbildung, XVII, 1920, Nr. 10 und 11.

von der Kulturhöhe abhängig, und so wird ohne weiteres klar, in welch hohem Masse die Volksdichte eines Gebietes durch seine Kulturhöhe bestimmt wird.

Dies ist von RATZEL [1] mehrfach sehr mit Recht betont worden; aber indem er fruchtbaren Boden mit dünner, armen Boden mit dichter Bevölkerung eigens würdigte, war er sich völlig inne, dass die Volksdichte nicht bloss von der Kulturhöhe, sondern namentlich auch von natürlichen Faktoren abhängt. Ausdrücklich hat er hervorgehoben, dass in den grossen Zügen der Verteilung der Bevölkerung über die Erde zuförderst die klimatischen Ursachen sichtbar werden [2]. Wir müssen eben immer beides, Gunst der natürlichen Bedingungen und Kulturhöhe, in Betracht ziehen, wenn wir die Volksdichte eines Gebietes erklären wollen. Mit ihrer Hilfe können wir durch den Vergleich verschiedener Gebiete den einen oder anderen Faktor ausschalten. Haben wir Gebiete gleicher Kulturhöhe, so können wir aus deren verschiedenen Volksdichten auf verschiedene Produktionskräfte schliessen und so zu einer Bonitierung der Erdoberfläche gelangen.

Dies gilt aber nur für geschlossene Wirtschaftsgebiete und nicht für Länder mit Export und Import von Nahrungsmitteln. Der Handel ermöglicht, dass an der einen Stelle Menschen von der Nahrung leben, die an der andern gewonnen wird, und die klare Beziehung zwischen Volksdichte, Produktionskraft und Intensität der Bodenkultur wird verwischt; aber nur ausnahmsweise geht sie gänzlich verloren. Länder mit Einfuhr von Nahrungsmitteln steigern ihre Volksdichte auf Kosten der Ausfuhrländer. Sei E die Einfuhr von Nahrungsmitteln eines Einfuhrlandes, bezogen auf die Einheit seiner Fläche, so ergibt sich die natürliche Volksdichte, die es haben würde, wenn kein Handel bestünde, aus der Gleichung:

$$\delta = \frac{Ki - E}{n}$$

und die eines Landes mit der Ausfuhr A von Lebensmitteln, wiederum auf die Einheit seiner Fläche bezogen, ist:

$$\delta = \frac{Ki + A}{n}.$$

Unsere beiden Formeln veranschaulichen auf das deutlichste, dass der Welthandel die natürlichen Volksdichten der einzelnen Länder mehrt oder mindert, aber er ruft keine allgemeine Steigerung der Zahl der Menschen auf der Erde hervor; diese ist und bleibt ausschliesslich abhängig von der Grösse und Produktionskraft der Erde und der Höhe der Bodenkultur (i) sowie von dem Nahrungsbedürfnis des einzelnen.

[1] Anthropogeographie II, 1891, S. 255. 279. [2] Ebenda S. 204.

Von diesen Faktoren können die beiden ersteren für die geologische Gegenwart als konstant angesehen werden; variabel sind nur die Intensität der Bodenkultur und, in beschränkterem Umfange, das Nahrungsbedürfnis des einzelnen. Solange dieses unveränderlich bleibt, schwankt die mögliche Zahl der Menschen auf der Erde lediglich mit der Höhe der Bodenkultur, aber diese kann über ein gewisses Maximum hinaus nicht zunehmen. Sobald allenthalben auf der Erde eine Höchstkultur des Bodens erreicht ist, kann die Zahl der Menschen nicht mehr zunehmen. Die so bestimmte Höchstzahl der Bevölkerung nennen wir die potentielle Bevölkerung, der eine potentielle Volksdichte D und die Kapazität der Länder entspricht.

Die grösstmögliche Zahl der Menschen auf der Erde hat E. G. RAVENSTEIN [1] im Jahre 1890 auf der Versammlung der British Association for the advancement of Science zu Leeds zu schätzen versucht. Er teilte die Landfläche in fruchtbare Gebiete, Steppen und Wüsten. Die fruchtbaren Gebiete decken sich mit den natürlichen Waldgebieten; er schreibt ihnen eine höchstmögliche Volksdichte von 83, den Steppen eine solche von 4, den Wüsten von 0.4 Einwohnern auf 1 qkm zu und berechnet daraus mit Hilfe der von ihm geschätzten Areale von Waldland, Steppe und Wüste die potentielle Bevölkerung der Erde zu 5994 Millionen. Freiherr VON FIRCKS [2] hält die von RAVENSTEIN angenommenen Volksdichten für zu gering, er kommt zu 9000 Millionen, indem er den fruchtbaren Regionen eine grösste mittlere Volksdichte von 100, den Steppen eine solche von 50, den Wüsten von 5 zuschreibt. Stellen wir einen von HERMANN WAGNER [3] bemerkten Rechenfehler richtig, so ergibt sich unter den von FIRCKS gemachten Voraussetzungen nur eine Kapazität der Erde für 7800 Millionen Menschen.

Einen anderen Weg schlug BALLOD ein[4]. Er schätzte die anbaufähige Fläche der Erde zu 55.6 Millionen qkm, wovon 28 Millionen qkm Ackerland sein könnten. Wenn nun in den Vereinigten Staaten von Amerika zur Ernährung eines Menschen 1.2 ha nötig seien, so könnten nach diesem Standard of life 2333 Millionen Menschen auf der Erde leben, nach dem deutschen (0.5 ha) wären es 5600 Millionen, nach dem japanischen (0.125 ha) 22400 Millionen. Den deutschen Standard of life als einigermassen menschenwürdig bezeichnend, hält BALLOD die Zahl von 5600 Millionen vorläufig für richtig. Dass die zur Ernährung des Menschen nötige Fläche nicht bloss vom Standard of life, sondern auch von der wechselnden Produktionskraft abhängt, erwägt er nicht. RATZEL [5] meinte, dass

[1] Lands of the Globe still available for European Settlement. Proceedings R. Geographical Society XIII, 1891, S. 27.

[2] Bevöklkerungslehre und -politik. Leipzig 1898, S. 295.

[3] Lehrbuch der Geographie, 10. Auflage 1923, S. 889.

[4] Wieviel Menschen kann die Erde ernähren? Schmollers Jahrb. f. Gesetzgebung, Verwaltung und Volkswirtschaft XXXVI, 2, 1912, S. 81.

[5] Anthropogeographie II, 1891, S. 228.

die 6/7 der Erde ausserhalb Europas, Indiens und Chinas mindestens 55 Millionen qkm von solcher Güte umschlössen, dass sie noch einige Milliarden zu ernähren imstande wären. HERMANN WAGNER hingegen wirft die Frage auf, ob die Erde die doppelte Zahl von Menschen, die sie heute trägt, zu ernähren vermöchte.

Unsere Darlegungen eröffnen die Möglichkeit, die angeführten auseinandergehenden Schätzungen, deren Unsicherheit aus der Unsicherheit ihrer Grundlagen ohne weiteres erhellt, in Zukunft durch genauere Berechnungen zu ersetzen. Sobald aus den wechselnden faktischen Volksdichten die potentiellen der einzelnen Teile der Landoberfläche errechnet sein werden, wird man die Höchstzahl der Menschen mit leidlicher Genauigkeit ermitteln können. Aber jene Grundlage fehlt noch und wir können die Höchstzahl der Menschheit, die bei intensivster Bodennutzung nach besten heutigen Methoden möglich ist, lediglich roh schätzen. Dabei leitet uns die Erwägung, dass das Klima sichtlich einen ganz massgebenden Einfluss auf die Produktion menschlicher Nahrung ausübt und damit die Volksmenge bestimmt. Wir setzen voraus, dass einem bestimmten Klima bei sonst gleichen Bedingungen eine bestimmte maximale Volksdichte zukommt, und wählen daher eine Klimaeinteilung zum Ausgange der Schätzung. Dafür empfiehlt sich die KÖPPENS [1] um so mehr, als HERMAN WAGNER [2] sich der Mühe unterzogen hat, deren einzelne Gebiete auszumessen. Nun kommen in jedem Klima besonders dicht besiedelte Landstriche vor, welche zwar gewiss nicht die höchste denkbare, aber wenigstens eine sehr hohe Kultur aufweisen. Denken wir uns das gesamte Klimagebiet mit der zugehörigen höchsten Volksdichte belastet, so erhalten wir jedenfalls einen Höchstwert seiner möglichen Einwohnerzahl; denn die Gebiete, die besonders dicht besiedelt sind, erfreuen sich in der Regel auch einer besonderen Gunst des Bodens. Doch dürfen wir nicht annehmen, dass jedes Klimagebiet ganz gleichmässig besiedelbar sei, denn dann müssten sich die Grenzen der einzelnen Klimagebiete als scharfe Trennungslinien von Gebieten verschiedener Volksdichten zu erkennen geben. Es ist auch klar, dass KÖPPENS feuchttemperiertes Klima im südlichen Irland nicht dieselbe Volksdichte haben kann wie im wärmeren Japan. In jedem Klimagebiete gibt es Abstufungen, die den allmählichen Übergang von einem Klimagebiete zum benachbarten vermitteln. Weitere Abstufungen ergeben sich notwendigerweise aus den verschiedenen Bodenverhältnissen. Ein heiss-

[1] Klassifikation der Klimate nach Temperatur, Niederschlag und Jahreslauf. PETERMANNS Mitteilungen LXIV, 1918, S. 193. Die Klimate der Erde. Berlin 1923. Hier wird auf WAGNERS Anregung hin der Name subarktische Klimate durch boreale ersetzt.

[2] Die Flächenausdehnung der KÖPPENS chen Klimagebiete der Erde.—PETERMANNS Mitteilungen LXVII, 1921, S. 215. Auf KÖPPENS Karte sind 1918 in der Farbenerklärung die Namen wintertrockenkalte und feuchtwinterkalte Klimate vertauscht worden, was auch in WAGNERS Tabelle III geschehen ist.

feuchtes Urwaldklima wird auf Laterit eine viel geringere Produktionskraft entfalten als auf vulkanischem Boden. Alles in allem dürften die dichtest besiedelten Teile der einzelnen Klimagebiete nicht bloss durch besonders hohe Bodenkultur, sondern auch durch besonders gute Bodenbeschaffenheit sich auszeichnen. Aus verschiedenen Gründen sind ihre Volksdichten für das einzelne Klimagebiet auch als optimale zu hoch. Wollen wir die potentielle Volksdichte eines grösseren Klimagebietes ermitteln, so müssen wir sie geringer als die höchste vorkommende ansetzen. Doch ist dies nicht ganz unserer Willkür überlassen; denn das Pflanzenkleid des Landes gibt einen guten Anhalt zur Schätzung der Abstufungen der Produktionskraft von Boden und Klima. Es ermöglicht uns, plausible Werte für die mittlere potentielle Volksdichte eines Klimagebietes aufzustellen, aus dessen von Wagner bestimmten Fläche wir die wahrscheinliche grösstmögliche Bewohnerzahl herleiteten. Im einzelnen wurde wie folgt verfahren:

1. Im feuchtwarmen Urwaldklima ragt die hochkultivierte Insel Java durch ihre Volksdichte von 266 Einwohnern auf 1 qkm besonders hervor; diese steigert sich im westlichen Teile der Insel auf 350. Dabei ist die Insel nur teilweise in Kultur genommen, und Woeikof [1] hält eine mittlere Volksdichte von 800 für möglich. Danach glaubt er, dass die ganze Tropenzone zwischen 15° N und 15° S durchschnittlich 400 Einwohner auf dem Quadratkilometer und 10 Milliarden im ganzen nähren könne. Wir bleiben hinter dieser Schätzung weit zurück, indem wir die höchste potentielle Volksdichte in feuchtheissem Klima zu 400 veranschlagen; denn die Verhältnisse auf Java sind aussergewöhnlich günstige. Die vulkanischen Aschenregen düngen den Boden immer aufs neue und hindern dessen Erschöpfung. Aber wir wissen durch Thorbecke [2], dass in Kamerun, dicht ausserhalb des Urwaldgebietes trotz Einschaltung einer zweijährigen Brache zwischen den einzelnen Jahren des Anbaus 200 Menschen, vom Quadratkilometer ernährt werden könnten. Würde men durch entsprechende Düngung die Brache ausschalten können, so könnten im Graslande am Urwaldsaume 600 Menschen auf dem Quadratkilometer leben. Diese Zahlen sollen nur veranschaulichen, wie hoch die Produktionskraft des feuchten tropischen Klimas werden kann. Wir überschätzen sie daher wohl nicht, wenn wir sie im Durchschnitt durch die Volksdichte 200 ausdrücken.

2. Das periodisch trockene Savannenklima muss eine erheblich geringere Produktionskraft haben, da die Trockenzeit die Vegetation unterbricht. Aber zur feuchten Jahreszeit, also während der Hälfte des Jahres, ist sie wohl so gross wie in den feuchtwarmen Tropen. In der Tat finden wir in ihrem Bereiche nirgends so hohe Volksdichten wie in jenen. Sie

[1] De l'influence de l'homme sur la terre. Annales de géographie X, 1901, S. 97 (211).

[2] Das Hochland von Mittel-Kamerun II, S. 60. Abhandlungen des Hamburgischen Kolonialinstituts XXXVI, 1916.

erheben sich in der Präsidentschaft Madras auf 115 trotz des Exports von Reis. Die natürliche Volksdichte würde hier 120 überschreiten. Wir nehmen als Mittelwert der potentiellen für das ganze Gebiet 90.

3. Die Steppenklimate liegen nur zu rund 1/4 in den Tropen, zu 3/4 in den beiden gemässigten Zonen. Hier wie da ist ihre Produktionskraft gering, wird aber stark, wo durchfliessende Flüsse Bewässerung ermöglichen. Am Rande gegen das wintertrockene kalte Klima finden wir im Dongebiete eine Volksdichte von 21, höher noch ist die benachbarter Gouvernements an der Wolga. Doch wagen wir nicht, diese Randlagen zur Berechnung der höchsten denkbaren Einwohnerzahl der Steppengebiete heranzuziehen und wählen dafür die Volksdichte 10; die wahrscheinliche potentielle Volksdichte veranschlagen wir zu 5, weil die ostasiatischen Steppen Bewässerung grossenteils ausschliessen.

4. Das Wüstenklima ist theoretisch, produktionsunfähig und sollte unbevölkert sein. Aber sobald Flüsse in sein Gebiet eintreten und dessen Bewässerung ermöglichen, gibt es Erträgnisse für eine grosse Bevölkerung. Ägypten ist das Schulbeispiel dafür. Seine 13 Millionen Bewohner und die der indischen Wüsten am Indus würden, auf alle Wüsten der Erde verteilt, denselben bereits eine Volksdichte von 1 geben. Diese wollen wir in unsere Rechnung einsetzen, obwohl auch einige Millionen in den Oasen Zentralasiens und des westlichen Nordamerika wohnen. Zur Berechnung der höchsten denkbaren Einwohnerzahl benutzen wir nicht den Wert von Ägypten, da dieser für einen ganz willkürlichen Ausschnitt des Landes gilt, sondern nehmen als höchste Dichte 3. Gleich dem Steppenklima liegt das Wüstenklima nur mit rund 5 Millionen Quadratkilometern in den Tropen, sonst ausserhalb.

5. Köppens warmes wintertrockenes Klimagebiet umfasst die die dichtest bevölkerten, sich selbst versorgenden grösseren Länder, nämlich Bengalen und das südliche China. Im letzteren, von den grossen Ebenen bis zum gebirgigen Szetschwan, leben auf 2 Millionen Quadratkilometern rund 320 Millionen Menschen, also 160 auf 1 qkm. In Bengalen steigert sich die Volksdichte auf 228, obwohl sich die Präsidentschaft von der Gangesebene bis tief in den Himalaja erstreckt. Aber wir dürfen kaum erwarten, dass bei ähnlich intensiver Bodenkultur wie in Vorderindien und China das gesamte warmtrockene Klimagebiet ähnlich grosse Volksdichten zu nähren vermöchte. Jene Länder geniessen die Vorteile des Monsuns, der anderen fehlt. Als mittlere potentielle Volksdichte des Gebietes nehmen wir nur 110, vermutlich zu wenig, an.

6. Das warme, sommertrockene Klima ist bezeichnend für die Uferländer des Mittelmeeres. Das Italiens wird gewöhnlich als ein Musterbeispiel eines hierher gehörigen Landes angeführt. Sein intensiver Anbau bringt die Produktionskraft seines Klimas vorzüglich zur Geltung, seine Volksdichte von 125 mag daher zur Berechnung der höchsten denkbaren Bevölkerung dienen, obwohl es Nahrung importiert und aus dem Mittel-

meerklima herausgreift; diesem schreiben wir insgesamt nur eine potentielle von 90 zu.

7. Die feucht-temperierten Klimate KÖPPENS weisen in Japan, soweit sie es einschliessen, also mit Ausnahme des Nordens, eine sehr hohe Volksdichte von nicht weniger als 220 auf. Auch in Europa sind sie dicht besiedelt. Freilich die Volksdichte des Deutschen Reiches (125) ist, wie sich im Kriege erwiesen hat, grösser, als durch das Land ernährt werden kann, während die Frankreichs (71) höher sein würde, wenn die Bodenkultur dort die Ödländereien mehr einschränken würde. 100 scheint uns die grösstmögliche in Europa zu sein; sie wurde selbst in Irland erreicht, bevor die starke Auswanderung die Bevölkerung der grünen Insel auf die Hälfte minderte. Damit dürfte wohl auch ein Mindestamass für die mögliche Volksdichte für die Südoststaaten der Union gegeben sein. Amerikanische Gelehrte sind darin einig, dass die Vereinigten Staaten viel mehr Menschen bergen könnten als gegenwärtig, und, wie BRIGHAM [1] richtig bemerkt, werden sie dabei leicht enthusiastisch. Aber er selbst wurde es nicht. Er schreibt dem Lande östlich der grossen Ebenen, das in das feucht-temperierte Klima fällt, nur eine mögliche Volksdichte von 40 zu. Das ist entschieden viel zu wenig. Die Verhältnisse Japans machen hier eine sehr viel grössere Dichte einer sich selbst versorgenden Bevölkerung wahrscheinlich, die allerdings genügsamer leben müsste als die heutigen Amerikaner. Wir überschätzen die potentielle Dichte der feucht-temperierten Klimate mit 100 gewiss nicht.

8. und 9. Die subarktischen oder borealen Klimate KÖPPENS umfassen weite Gebiete in der alten und neuen Welt, die sich vom Bereiche der feucht-temperierten Länder und der Steppen bis zur Tundra ziehen. Ihre Produktionskraft ist an der Grenze der ersteren ansehnlich, wie trotz rückständiger Bodenkultur die Volksdichte (106) jenes Teiles von Polen lehrt, der bislang als Kongresspolen bezeichnet wurde, und wie jene der chinesischen Provinz Tschili (96) ohne Peking lehrt. Aber gegen die Tundra hin ist die Produktionskraft naturgemäss gering. Indes leben, allerdings nicht als reine Selbstversorger, in Finnland noch beinahe 10 Menschen auf 1 qkm, und eine Steigerung des Anbaus scheint dort immer noch möglich. Die produktionskräftigen subarktischen Gebiete sind die der ziemlich hohen Sommertemperatur, die Dfa-, Dfb- und Dwa-Klimate KÖPPENS. Hier erscheinen Volksdichten von 80 noch möglich, in den Dfc- und Dfw-Gebieten durchschnittlich aber nur solche von 10. Im Mittel schreiben wir den borealen Klimaten KÖPPENS, sowohl den feuchtwinter- als auch den trockenwinterkalten, eine potentielle Volksdichte von 30 zu.

10. Das Tundrenklima spendet nur indirekt Nahrung durch Vermittlung der Tiere, namentlich der Renntiere, sowie animalische Nahrung an

[1] Capacity of the United States for population. Popular Science Monthly. 1909, S. 209.

den Küsten. Seine produktive Kraft ist äusserst gering, wenn auch VILHJÁMUR STEFÁNSSON von einer freundlichen Arktis spricht[1]. Schon südlich von ihm finden sich in den nördlichsten Dörfern Finnlands kaum 0.1 Einwohner auf 1 qkm. Die 700000 qkm eisfreien Landes in Grönland ernähren nur 13000 Menschen. Es hängt die Zahl der Menschen in diesen Gebieten nicht ab von ihrem Fleiss, den Boden zu bebauen, sondern der Menge des jagdbaren Wildes. Verbesserte Jagdmethoden, namentlich die Anwendung von Feuerwaffen, vermögen das Erträgnis der Jagd zu steigern, mindern aber zu leicht dauernd die Menge des Wildes. Nur wenn das Abschiessen nicht grösser als die natürliche Vermehrung ist, kann der Mensch sich hier dauernd halten; das Beste, was er tun kann, um seine Existenz hier zu sichern, ist die Bekämpfung der Raubtiere, des Eisbären und des Wolfes, die seine Nahrung, Seehund und Renntier, mindern. Mit 0.01 setzen wir die mögliche Volksdichte in diesen Gebieten kaum zu niedrig an.

11. KÖPPENS Klima des ewigen Frostes deckt sich mit dem Bereiche der Inlandeismassen des hohen Nordens und Südens, die natürlich menschenfrei sind.

In folgender Tabelle stellen wir die 11 Klimagebiete KÖPPENS mit ihren von HERMANN WAGNER bestimmten Flächeninhalten zusammen; wir führen ihre dichtest besiedelten Gebiete an und die Volksdichten, nach

Klimate	I Flächeninhalt (Millionen qkm)	II Dichtest besiedelte Länder darin mit ihrer Volksdichte sowie angenommene grösste Volksdichte (Einw. auf 1 qkm)		III Höchste denkbare Einwohnerzahl (Millionen)	IV Wahrscheinliche mittl. Volksdichte (Einw. auf 1 qkm)	V Wahrscheinliche grösstmögliche Einwohnerzahl (Millionen)
1. Feuchtheisse Urwaldklimate	14.0	Westjava (400)	350	5600	200	2800
2. Periodisch trockene Savannenklimate	15.7	Madras	115	1806	90	1413
3. Steppenklimate	21.2	Dongebiet (10)	21	212	5	106
4. Wüstenklimate	17.9	Ägypten (3)	14	54	1	18
5. Warme wintertrockene Klimate	11.3	Bengalen	228	2576	110	1243
6. Warme sommertrockene Klimate	2.5	Italien	125	312	90	225
7. Feuchttemperierte Klimate	9.3	Südjapan	220	2046	100	930
8. Winterfeuchte kalte Klimate	24.5	Kongresspolen	106	2597	30	735
9. Wintertrockene kalte Klimate	7.3	Tschili	96	701	30	219
10. Tundraklimate	10.3	Grönland	0.02	0	0.01	0
11. Klimate ewigen Frostes	15.0	Antarktika	0	0	0	0
Gesamte Landoberfläche	149.0		(107)	15904	51	7689

[1] The Friendly Arctic. New York 1922 (Länder der Zukunft. Leipzig 1923).

denen wir die höchste mögliche Einwohnerzahl berechnen; endlich geben wir ihre wahrscheinliche potentielle Volksdichte und die daraus hergeleitete wahrscheinliche potentielle Einwohnerzahl an.

Aus unserer Tabelle erhellt, dass die höchste denkbare Einwohnerzahl der Erde 15.9 Milliarden ist, welche eine mittlere Volksdichte von 107 voraussetzen würde. Diese Zahlen erscheinen uns als ein äusserster Grenzwert, welcher schwerlich erreicht werden dürfte. Die wahrscheinlich grösste Einwohnerzahl der Erde ergibt sich nur halb so gross, zu 7.689 Milliarden, also unwesentlich anders als nach der berichtigten Schätzung von Fircks. Wir beleuchten die Genauigkeit dieser Zahl, indem wir die Klimagebiete der Erde ins Auge fassen, deren potentielle Volksdichte wir vermutlich zu niedrig angesetzt haben. Nehmen wir sie im periodisch trockenen Savannenklima (2), im warmwintertrockenen Klima (4), im feuchttemperierten (7) um 10 höher an, nämlich zu 100, 120 und 110, und geben wir den Wüstenklimaten 2 Bewohner auf 1 qkm, so erhalten wir bereits 381 Millionen mehr als errechnet. Es ist also unser Schlussergebnis bereits in den Hunderten der Millionen unsicher, und wir dürfen es unbedenklich auf 8 Milliarden aufrunden. Aber auch diese Zahl erscheint noch keineswegs gesichert. Sie erhöht sich um 1.4 Milliarden, wenn wir als potentielle Dichte des feuchtheissen Urwaldklimas das Mittel aus Woeikofs und unserer Schätzung annehmen. Es dürfte sich die potentielle Bevölkerung der Erde zwischen 8 und 9 Milliarden bewegen. Dem steht eine faktische von rund 1.8 Milliarden gegenüber. Es ist also der Lebensraum der Menschen nur etwa zu $\frac{1}{5}$ erfüllt. Sind nicht wenige Länder relativ übervölkert, d. h. übertrifft ihre faktische Bevölkerung ihre natürliche, sind einige absolut übervölkert, d. h. überschreitet ihre faktische Bevölkerung ihre potentielle, so ist das gesamte Land noch ziemlich weit von Übervölkerung entfernt. Diese würde nach unserer Berechnung erst eintreten, wenn 50–60 Menschen, und nicht bloss wie heute deren 12 im Durchschnitt auf 1 qkm wohnen würden.

Köppens tropische Regenklimate, nämlich die Urwald- und die Savannenklimate, fallen ganz in das Bereich der Tropen, die dünn besiedelten Steppen- und Wüstengebiete nur teilweise mit je 5 Millionen qkm, ebenso die warmen wintertrockenen Gebiete mit 7 Millionen qkm. Von den 8 Milliarden potentieller Bevölkerung der Erde entfallen $\frac{5}{8}$ auf die Tropen und $\frac{3}{8}$ auf die gemässigte Zone. Hier wäre die grösstmögliche Volksdichte 34, in den Tropen 107. Nicht nennenswert ist die Zahl der Menschen, die sich in den Polargebieten ernähren könnten. In der Tatsache, dass die Tropen mehr als dreimal so dicht besiedelt werden könnten als die gemässigten Zonen, spiegelt sich die starke Beeinflussung der Produktionskraft der Erde durch das Klima. Nehmen wir die potentielle Bevölkerung der Erde zu 9 Milliarden an, so tritt dies noch deutlicher hervor, dann ergibt sich die Bewohnerschaft der Tropen zu $\frac{2}{3}$ der ganzen Menschheit, und die grösstmögliche Volksdichte wird hier 128. Heute ist es anders.

Von den rund 1.8 Milliarden, die gegenwärtig die Erde bewohnen, entfallen 1.3 Milliarden (72 Prozent) auf die gemässigten Zonen, nur 0.5 Milliarden (28 Prozent) auf die Tropen[1].

Die Tropen sind, wie namentlich auch WOEIKOF [2] ausgesprochen hat, das Gebiet der grossen Menschenanhäufungen der Zukunft, während es heute die gemässigten Zonen sind. Die faktische Verteilung der Menschheit auf der Erde bringt den Einfluss des Klimas weit weniger zum Ausdruck als die potentielle. Wie eng die Beziehungen der letzteren zum Klima sind, erhellt, wenn wir die von KÖPPEN unterschiedenen Klimagebiete nach den Gesichtspunkten gruppieren, die ich früher entwickelt habe[3]. Es ergibt sich folgende Reihe:

Klimagebiete (PENCK)	nival	seminival	humid (temperiert)	humid (tropisch)	semihumid	semiarid	arid
" (KÖPPEN)	(11)	(10.9.8)	(7)	(1)	(6.5.2)	(3)	(4)
Potent. Volksdichte	0	23	100	200	98	5	1
Anteil der Menschheit	0	12.4%	12.2%	36.3%	37.5%	1.4%	0.2%

Wir sehen die warmfeuchten Klimate mit stärkster potentieller Volksdichte. Letztere sinkt mit abnehmender Temperatur zum nivalen Klima und mit abnehmendem Niederschlage zum ariden Klima. Nivales, seminivales, temperiert und tropisch humides Klima bilden den aufsteigenden, semihumides, semiarides und arides den absteigenden Teil der Reihe. Die von uns vorausgesetzte enge Beziehung zwischen Produktionskraft des Klimas und potentieller Volksdichte wird in dieser Reihe erwiesen.

So weit wir heute noch von einer Übervölkerung der Erde entfernt sind, so ist doch kein Zweifel, dass wir ihr entgegengehen, und zwar mit Riesenschritten, wenn die Vermehrung der Menschheit in den nächsten Jahrhunderten so rasch geschieht wie im Laufe der letzten 50 Jahre. Während dieses Zeitraumes schätzt HERMANN WAGNER die Zunahme der Bevölkerung der Erde zu 425 Millionen Menschen[4]; dem entspricht eine jährliche Zunahme von 0.57 Prozent. Geht es in diesem Tempo weiter, so ist der Lebensraum der Menschen in weniger als 300 Jahren erfüllt, und der der gemässigten Zonen bereits in etwa 150 Jahren. Viel eindringlicher als das Gesetz von MALTHUS lehrt uns unsere Betrachtung, dass die Zahl der Menschen auf der Erde eng begrenzt ist, und zwar nicht deswegen, weil die Vermehrung der Bevölkerung in anderer Proportion erfolgt als die

[1] SAPPER gibt 569 Millionen an, rechnet aber ganz Britisch-Indien zu den Tropen, was wirtschaftsgeographisch zulässig ist, hier aber nicht getan werden kann. (Die Tropenländer in ihrer Bedeutung für deutschen Kolonialbesitz und Weltwirtschaft. Geogr. Zeitschr. XXIV, 1918, S. 385.)

[2] Verteilung der Bevölkerung auf der Erde unter dem Einfluss der Naturverhältnisse und der menschlichen Tätigkeit. PETERMANNS Mitteilungen 1906, S. 241 (247).

[3] Versuch einer Klimaklassifikation auf physiogeographischer Grundlage. Sitzungsber. d. phys.-math. Kl. d. Preuss. Akad. d. Wissensch., Berlin 1910, S. 236.

[4] Lehrbuch der Geographie, 10. Auflage, 1923, S. 739.

Vergrösserungsmöglichkeit der Nahrung, sondern weil die letztere wegen der Beschränktheit der Nährfläche begrenzt ist. Hier liegt das grosse Problem der Wirtschaftsgeographie. Solange sich die Menschheit auf der Erde vermehrt, ist unausbleiblich, dass einmal die Erfüllung der Erde erfolgt, früher oder später.

Die von MALTHUS empfohlene Selbstbeschränkung in der Vermehrung der Menschheit scheint uns aber so lange nicht geboten, als noch Raum für viele vorhanden ist. Dass dies der Fall ist, ergab sich bisher aus unserer Untersuchung. Ob der Raum sich auf die Dauer so rasch füllt wie in den letzten 50 Jahren, kann billig bezweifelt werden. Die grosse Ausdehnung des Verkehrs im letzten Halbjahrhundert erschloss weite Gebiete der Erde der Kultur, die vorher brach lagen und die mühelos besetzt werden konnten. Solcher leicht benutzbarer Boden begünstigt die Vermehrung der Menschheit. Sobald wieder mit Mühe unter Widerwärtigkeiten Gebiete erobert werden müssen, wird so mancher Arbeiter erliegen; namentlich wird die Rodung des tropischen Urwaldes grosse Opfer an Menschen erheischen. Eine Verlangsamung in der Vermehrung der Bevölkerung der Erde wird dabei von selbst eintreten und braucht nicht durch eine Selbstbeschränkung erstrebt zu werden, welche vielleicht das Geborenwerden der Tüchtigsten hindert. Aber an die bevorstehende Erfüllung der Erde muss die Wirtschaftsgeographie immer denken, es gibt kein Land der unbegrenzten Möglichkeiten, und ihre Aufgabe besteht in erster Linie darin, auf die Hilfsmittel der Natur hinzuweisen, welche dem Menschen auf der Erdoberfläche zur Verfügung stehen. Die Art ihrer Nutzung ist Aufgabe der Wirtschaftslehre. Nicht durch Betrachtung der geographischen Verbreitung menschlicher Arbeit erschöpft die Wirtschaftsgeographie ihre Aufgabe. Sie ist eine Wissenschaft von natürlichen Gegebenheiten und deren örtlicher Ausnutzung. Im Mittelpunkte steht für sie die begrenzte Möglichkeit der Nahrungsbeschaffung für die ewig hungrige Menschheit. Die Agrargeographie ist der eigentliche Kern der Wirtschaftsgeographie, und diese erscheint Berufen, bei einem grossen Plane über die rationellste Bewirtschaftung der Erde ein entscheidendes Wort mitzureden. Erfreulicherweise beginnt sie mehr und mehr die Landbauzonen zu würdigen und nicht bloss mehr statistische Tabellen über Verkehr und Produktion zu paraphrasieren.

Nicht weniger bedeutungsvoll wie für die Wirtschaftsgeographie ist das hier behandelte Hauptproblem der physischen Anthropogeographie für die politische Geographie. Sobald wir die potentielle Volksmenge derselben ins Auge fassen, werden wir sie besser würdigen, als wenn wir sie bloss nach Flächeninhalt und Einwohnerzahl klassifizieren, denn wir sehen nicht bloss Vorhandenes, sondern auch Mögliches, das die Zukunft erschliessen kann. Fassen wir die auf zusammenhängender Landfläche sich dehnenden Staaten ins Auge, so ist heute Sowjetrussland der grösste und das chinesische Reich der an Einwohnern reichste. Brasilien aber erscheint als

derjenige mit der grössten potentiellen Bevölkerung; es kann nahezu 1200 Millionen bergen. Gross sind trotz starker Bevölkerung auch die potentiellen Möglichkeiten in China; ich schätze dessen grösstmögliche Bevölkerung auf mehr denn 600 Millionen Einwohner und halte sie für grösser als die von den Vereinigten Staaten und Russland mit rund 600 Millionen. Aber auch für das britische Weltreich mit den Gebieten, wo die weisse Bevölkerung herrscht, nämlich in dem absolut übervölkerten Stammlande mit einer potentiellen Bevölkerung von 30 Millionen, mit Canada (60 Millionen), der südafrikanischen Union (60 Millionen) und der Commonwealth von Australien (450 Millionen), ergibt sich nur eine mögliche Bevölkerung von 600 Millionen. Die beiden grossen angloamerikanischen Mächte bieten zusammengenommen nur ebenso viel Raum für weisse Bevölkerung wie die Vereinigten Staaten von Brasilien für ihre zukünftige Bewohnerschaft und wie die hispano-amerikanischen Staaten zusammengenommen (1200 Millionen). Man sieht, welche gewaltigen Zukunftsmöglichkeiten bei den portugiesisch und spanisch redenden Völkern liegen, und dass sie—gleiche Grenzen für ihre Staaten auch in Zukunft vorausgesetzt—, das anglo-amerikanische Element von seiner gegenwärtigen dominierenden Stellung verdrängen können. Welche Verschiebungen in der Bevölkerung der einzelnen Erdteile denkbar sind, erhellt aus folgender Tabelle:

	Erde	Eurasien	Afrika	Australien	Nord-amerika	Süd-amerika
Faktische Bevölkerung 1920	1.8 Milliarden	80%	7%	0.5%	9%	3.5%
Potentielle Bevölkerung	8.0 "	26%	29%	6%	14%	25%

Unsere Tabelle lässt ahnen, dass grosse geschichtliche Umwälzungen die zunehmende Erfüllung der Erde mit Menschen begleiten werden. Eurasien kann seine führende Rolle als Hauptherd der Menschheit an Afrika verlieren, denn es vermag schliesslich nicht viel mehr als ¼ der Menschen zu nähren, während es heute ⅘ derselben beherbergt. Nordamerika, das sich seit mehr als einem Jahrhundert rasch mit Menschen füllte und heute einen grossen Teil der Menschheit mit Nahrung versorgt, kann bei maximaler Leistung kaum mehr als halb soviel wie sein südlicher Nachbar produzieren und wird bei Erfüllung der Erde mit Menschen an vorletzter Stelle unter den Erdteilen stehen. Aber es muss im Auge behalten werden, dass nur die Summe der Menschen und nicht unbedingt die Verteilung der Menschen auf der Erde durch die Produktionskraft des Landes bestimmt werden. Wie heute kann auch in Zukunft der Verkehr ermöglichen, dass die Menschen an einer Stelle der Erde die Früchte verzehren, die eine andere hervorgebracht hat. Das ist die grosse Frage, ob die Tropen, wenn sie das Hauptproduktionsgebiet menschlicher Nahrung geworden sind, auch zugleich Sitz der grössten Menschenmenge geworden

sein werden, oder ob sie, wie FRIEDRICH LIST meinte, bloss die Kornkammern für die Länder der gemässigten Breiten sein werden, wo nach HUNTINGTON der Sitz der grössten Arbeitsenergie und dementsprechend der Zivilisation ist. Für Entscheidung dieser wichtigen Zukunftsfrage kommt in Betracht, ob der Verkehr, der im letzten Jahrhundert so manche Schranke zwischen den Ländern zum Fallen brachte und durch seine neuen Mittel sich von den durch die Natur vorgezeichneten Bahnen vielfach frei machte, seine gegenwärtige Bedeutung auch für alle Zukunft beibehalten kann. Beruht er doch auf der Ausbeute der Schätze von Kohle und Eisen in der Erde, die ebenso begrenzt sind, wie die für die Nahrungsmittelproduktion verfügbare Fläche. Was nun aber auch eintreten möge, sicher bleibt das eine: es spielt sich das menschliche Leben auf einer beschränkten Fläche ab, und es kann die Zahl der Menschen über ein gewisses Mass nicht hinauswachsen. Diese wichtigste Grundlage für die geschichtliche Betrachtung des Menschengeschlechtes liefert die Erdkunde: Es läuft die menschliche Entwicklung, solange sie fortschreitet, einem bestimmten Ziele zu. Geographisch bedingt ist die Ausbreitung der menschlichen Kultur. Sie beginnt dort, wo die Bodenkultur leicht ist, wo der Boden nur bewässert zu werden braucht, um Erträgnisse zu liefern. In Wüsten und Steppen liegen die Wurzeln der alten Kultur Ägyptens und Mesopotamiens. Sie schreitet von hier zu den sommertrockenen Ländern des Mittelmeeres und zu den Monsunländern Asiens. Dann erst beginnt die grosse Kulturarbeit in der Rodung der Wälder an der Grenze der feuchttemperierten und kalten Klimate durch germanische Völker, erst in der alten Welt, zuletzt in der neuen. Hier wieder dringt sie mehr und mehr in die kalten Gebiete und hat hier die Grenzen des Möglichen noch nicht erreicht. In der Tropen hat sie bisher lediglich auf den Hochländern Fuss gefasst, am frühsten in Dekkan, aber auch in Abessinien und in Amerika, in Mexiko und in Peru. In die feuchtheissen Urwälder ist sie jedoch noch nicht herabgestiegen. Hier bleibt noch die grösste Kulturarbeit der Menschheit zu lösen. Die entgegenstehenden Hindernisse sind so gross, dass es der stärksten Notwendigkeit bedarf, sie zu überwinden. Das Nahrungsbedürfnis der wachsenden Menschheit wird dazu zwingen. Der Hunger, die kräftigste Ursache instinktiven menschlichen Handelns, wird es bewirken.

Gegenüber der hohen potentiellen Bevölkerung der Erde bleibt die faktische weit zurück. Darf das ferne zu erreichende Ziel bei keiner geographischen oder historischen Betrachtung ausser acht gelassen werden, so steht doch das momentan erreichte im Vordergrund geographischen Interesses. Zu einer vollen Würdigung der Bedeutung der faktischen Volksdichte gehört nicht bloss der Vergleich mit der natürlichen, durch den Verkehr gemehrten oder geminderten, sondern zugleich auch das Defizit, das die natürliche gegenüber der grösstmöglichen aufweist. Erst dieses Bevölkerungsdefizit gibt uns das wahre Verständnis der Gesamtbevölker-

ung eines Landes, ob sie der Auffüllung rasch entgegengeht oder noch weit davon entfernt ist.

Nach unserer früheren Aufstellung hängt die faktische Bevölkerung eines Gebietes von dessen Produktionskraft und der Intensität der Bodenkultur ab. Das Bevölkerungsdefizit eines Landes erscheint hiernach als ein Defizit seiner Bodenkultur und, sofern man letztere als den Ausdruck seiner Kulturhöhe ansieht, als ein Kulturdefizit. Das trifft für viele Fälle entschieden zu. Alle die Länder, die wir in unserer Tabelle S. 251 als dichtest besiedelte der einzelnen Klimagebiete zur Schätzung von deren Kapazität für Menschen genommen haben, sind Gebiete mehr oder weniger hoher Kultur. Aber voll trifft nicht zu, dass die andern Länder jener Gebiete deswegen von niederer Kultur seien. Es gibt darunter viele, die eine wenig dichte natürliche Bevölkerung besitzen und doch hohe Kultur haben; ein U.-S.-Amerikaner würde wegen der geringen Volksdichte der Oststaaten gewiss nicht zugeben, dass er kulturell dem dichter wohnenden Japaner unterlegen sei. Das Bevölkerungsdefizit eines Lande hängt sowohl von der geringen Intensität der Bodenkultur wie auch vom Alter der Gesamtkultur daselbst ab. Was mehr oder weniger massgebend ist, ist von Fall zu Fall zu untersuchen, wobei besonders im Auge zu behalten ist, dass die junge Kultur, möchte sie auch noch so hoch sein, in der Regel mit einer geringen Intensität der Bodenkultur Hand in Hand geht. Hier eröffnen sich für zukünftige Forschungen weite Perspektiven. Hier bietet sich ein Weg zur Gewinnung von Massstäben für die Kulturhöhe von Völkern.

Unser Hauptproblem der Anthropogeographie hat mit allen Zweigen derselben Fühlung, welche sich nach Nachbarwissenschaften strecken, sowohl mit der Wirtschaftsgeographie als auch mit der politischen Geographie, mit der historischen Anthropogeographie und der Kulturgeographie im engeren Sinne des Wortes. Es knüpft alle diese Disziplinen eng an die Physiogeographie, mit der sie bisher zu wenig Fühlung batten. Daring wurzelt ihr vielfach unbefriedigender Zustand, der hinsichtlich der Wirtschaftsgeographie nicht bloss vom Weltwirtschaftler beklagt wird[1], der aber nicht beseitigt wird, wenn man sie bloss mit den Nachbarwissenschaften in engere Berührung bringt, ohne ihre Beziehungen zur Geographie im engeren Sinne zu stärken. Nur wenn man in allen jenen Disziplinen von der Erdoberfläche ausgeht, wird man ihren geographischen Inhalt völlig zur Geltung bringen. Geht man, wie bisher vielfach geschehen, vom Menschen aus, so zieht man sie zu den Nachbarwissenschaften hinüber und bringt diesen nicht das, was sie brauchen und sich nicht selbst zu beschaffen in der Large sind, nämlich die Fühlung mit der Erdoberfläche, dem Schauplatze der menschlichen Wirtschaft und Staatenbildung, der Weltgeschichte und Kultur.

[1] Bernhard Harms, Volkswirtschaft und Weltwirtschaft. Versuch der Begründung einer Weltwirtschaftslehre. Probleme der Weltwirtschaft VI, 1912, S. 407.

Wie die Ermittlung der Eisen- und Kohlenvorräte eine Aufgabe der praktischen Geologie ist, welche damit der Wirtschaftslehre wichtige Grundlagen geliefert hat, so ist die Bestimmung des dem Menschen zur Verfügung stehenden kulturfähigen Landes eine Hauptaufgabe der Geographie. Was in der vorliegenden Arbeit in dieser Hinsicht unternommen wurde, ist ein Versuch, Dinge zu schätzen, die gegenwärtig noch nicht erfasst worden sind. Sollen die angeschnittenen Aufgaben näher verfolgt werden, so muss eine Bonitierung der Erdoberfläche vorgenommen werden, bei welcher viel kleinere Gebiete, als hier geschehen, in bezug auf ihre Produktionskraft ins Auge gefasst werden müssen, wenn es auch nicht praktisch durchzuführen wäre, dabei so ins einzelne zu gehen wie bei den Bonitierungen unserer Gemeinden. Gewiss kann man dieselben auch bei einzelnen Untersuchungen heranziehen, aber fürs erste ist es nötig, ansehnlichere Flächen nach Klima und Bodenbeschaffenheit näher zu erforschen. Nur ein Physiogeograph, der mit Boden und Klima näher vertraut ist, kann eine solche Aufgabe lösen. Er wird dabei wesentlich gefördert werden, wenn er, wie es A. K. Cajander [1] bei Bonitierung der finnischen Forste tut, dem Auftreten charakteristischer Pflanzengemeinschaften volle Aufmerksamkeit schenkt. Will er dann, wie es rätlich ist, die Produktionskraft des Bodens gleich durch die Zahl der Menschen ausdrücken, die von der Flächeneinheit ernährt werden können, dann muss er Standardwerte über die Produktionskraft an gewissen Stellen zur Verfügung haben, die auf Musterwirtschaften zu gewinnen oder aus dem Ergebnis von Ernteerträgen herzuleiten wären. Weiter wäre der Konsumptionsbedarf des einzelnen zu bestimmen, und zwar nicht bloss nach dem ortsüblichen Verbrauch von Lebensmitteln, sondern auch auf dem Wege streng physiologischer Forschung.

Es ist selbstverständlich, dass nicht alles Land der Erde, und möchte es von noch so guter Beschaffenheit sein, ausschliesslich für Gewinnung der menschlichen Nahrung verwendet werden kann. Kleidung, Holzbedarf, Verkehr und Wohnstätten beanspruchen ansehnliche Teile der Oberfläche, und zwar wegen Kleidung und Erwärmung in den höheren Breiten viel grössere als in niederen. Aufgabe einer geographisch orientierten Weltwirtschaft wird sein, diese Flächen so auszuwählen, dass das Gesamterträgnis der Erde an Nahrung, Kleidung und Holz ein Maximum wird und ein Minimum von Kräften für den Transport vom Orte der Gewinnung zum Orte des Gebrauchs erheischt. Von einer solchen idealen Weltwirtschaft sind wir allerdings noch sehr weit entfernt. Noch steht die Volkswirtschaft in erster Linie des Interesses, und sie hat noch nicht einmal in den bestkultivierten Staaten eine streng rationelle Gliederung der Bodenproduktion durchsetzen können. Noch müht sich der Bauer auf kargem Boden zu ernten, während der beste daneben aus Gründen der

[1] Über Waldtypen. Acta forestalia fennica. I. Helsingfors 1913, S. 155. Über Waldtypen. II. Ebenda XX. 1922, S. 11.

historischen Entwicklung manchmal noch vom Walde eingenommen wird. Noch fehlt vielfach die zwingende Notwendigkeit, mit dem Überlieferten zu brechen. Aber diese Notwendigkeit wird kommen in dem Masse, als sich die Erde mit Menschen füllt.

RUSSIAN SOIL SCIENCE

Dr. K. D. Glinka gave a brief history of Soil Science as developed in Russia.

DOKUCHAIEV'S IDEAS IN THE DEVELOPMENT OF PEDOLOGY AND COGNATE SCIENCES

Dr. K. D. Glinka

Soil Science or Pedology is one of the branches of science, in which the researches of Russian pedologists must be awarded an honorary place, and that opinion has lately been shared by many scientists of Western Europe (10, 108, 109, 132, 133)[1]. It would not be too much to say that Russian scientists have created that branch of knowledge, if under the creation of a scientific discipline a clear definition of the matter studied and of the scientific problems arising therefrom may be understood. Foremost among them was Professor V. V. Dokuchaiev (1846–1903), who may be justly considered as the founder of Soil Science in Russia; his fundamental principles have been first laid down and published during the years 1879–1883 (16, 20).

One of these principles, that of *geographicity* (i.e., dependence of the character of a soil on its geographical position), was the result of Dokuchaiev's personal observations on the distribution of soils over a great extent of the surface of the European part of U.S.S.R.

Many scientific workers have called attention to facts, exhibiting the connection between climate and soils, but neither they nor their works can be mentioned here for want of space (120). These facts, relating to the organic part of the soil (humus, peat) and to the processes in the mineral part of same (weathering) had not, however, as yet given sufficient material for deductions and generalization.

The idea of the geographicity of soils nevertheless, if seriously considered, may lead us to some very important logical deductions. First of all it is obvious that, inasmuch as the elements of climate (the combination of temperature and moisture) effect the distribution of soils, soils are liable to modify their nature not only with the changes in warmth and moisture, depending upon latitude, longitude and altitude, but also with variations, due to comparatively small differences in the relief; this is

[1] See also in the compliments of West European scientists on the occasion of the creation of the Dokuchaiev Soil Committee. Bulletin of the Dokuchaiev Soil Committee, 1913, No. 1.

quite natural, since the "*micro-climate*," as is now called the combination of temperature and moisture above the very surface, as well as in the depth of the soil itself—is subject to changes with every small variation of the relief.

This is why the principle of *geographicity* of soils implies that of its *topographicity*, i.e. the connection between the nature of the soil and the relief. Furthermore, since local changes of the elements of climate are not only dependent upon the conformation of the surface, but also on the character of vegetation with which it is covered (as forest, steppe, etc.), the connection between soil and *vegetation* becomes evident. Finally, since the heating and the cooling, the moistening and the drying of the earth's surface partially depend upon the character of the underlying rocks, the connection between soil and *parent rock* is sufficiently obvious.

It is a matter of general knowledge that the above mentioned factors of soil formation, climate, vegetation and relief of the surface, are not invariable. They may have differed in the recent past or in distant, geological time, and where dry-land has existed for a long time, soils may have changed their aspect feebly, or more or less intensely. The factors of soil formation remaining uniform for a long period of time, it is to the duration of the soil processes that the character of soil is due.

The following two deductions may be made from the above: (1) the establishment of a connection between the *soil* and the *soil and geological history* of a certain part of the earth's surface, and (2) the assumption of the necessity of *evolution* of the soil with the change in the conditions of soil formation. In reading the works of Dokuchaiev, we may not perhaps be able to perceive clearly enough that the above mentioned deductions are derived from the fundamental principle of the geographicity of soils; still it is well known what great importance Prof. Dokuchaiev attributed to the following factors: relief of the surface, parent rock, character of vegetation, and geological age of the land. The evolution of the soils with the change of conditions of soil formation has been established as a fact by another Russian scientist, S. I. Korzhinski, Member of the Academy of Sciences (62), who observed the alteration in soils, caused by the growth of forests over tracts formerly occupied by steppes, to which in the particular case of chernozem soils, accordingly, he gave the name of degradation. Yet another scientific worker, P. A. Kostychev (66, 67), studied these processes of degradation in a laboratory. Subsequently other facts connected with the evolution of soils have been dealt with in Russian literature: changes, arising under the influence of forest-growth in alkali-soils (95) and in meadow-soils (107), podsolization of the ancient (Tertiary?) subtropical red-soils (35); opinions have been reached on the restoration (regradation) of chernozems under forests (76, 77).

One consequence, however, of the principle of geographicity of soils that must be considered as the most important of all, is the idea that the

soil is an independent natural body. This notion was first put forward prior to Dokuchaiev by F. A. Fallou, but being unsupported by evidence, however, then remained unobserved.

As a matter of fact, as the most important part of the soil mass—90 to as much as 99 per cent—is composed of mineral complex, it is clear that the majority of investigators were inclined to consider the soil as one of the loose sediments. Such a view rendered it difficult to distinguish soils from other rocks, especially from loose sediments. And yet these views were recorded in the works of the very searchers, who attempted to separate the soil as a distinct natural body.

Thus, in the classification of Fallou (27) and his followers, among which was the famous Richthofen, the soils were not clearly separated from other loose sediments of mechanical origin, and even from rocks formed through chemical precipitation (97). This circumstance is somewhat astonishing since Richthofen was one of the investigators, who had grasped the idea of geographicity of soils, and could therefore have been able to logically connect it with the notion of the soil, as an independent natural body. Richthofen was probably hindered in that course by his assumption of the regionality of the dynamic processes of the earth's surface, which he was developing in his works, that assumption being absolutely incompatible with the idea of geographicity. The fact is that under geographicity we mean the existence of a necessary connection between the present distribution of climatic elements and the geography of soils; whereas regionality, as described by Richthofen, had frequently no connection whatever with the present conditions of the climate. As instances of this statement may be adduced that the regions of glacial denudation, glacial accumulation, fluvial denudation, abrasion, and of volcanic deposits, exist on the earth's surface quite independently of the present climatic conditions.

The extension of rocks on the surface, when observed, shows that the distribution of granites, diabases, diorites, gneisses and schists, limestones and dolomites, sandstones and deposited clays, is not subject to any geographical law. All these rocks can be found in any climatic region, from the Pole to the tropics. That, however, is not the case with soils: laterites can not be formed in polar regions, neither can podsols and chernozems be found on the plains of the humid tropical regions. Therefore, if laterites, podsols and chernozems, as complexes of some mineral species, may be called rocks, it is obvious that they differ in some respect from all other rocks. Thus, there is sufficient reason for considering the soils as an independent group of natural bodies, requiring the establishment of a separate branch of science dealing with these peculiar bodies of Nature.

It would be interesting to point out that the idea of the peculiar character of soils, previously established by Dokuchaiev, was subsequently

dealt with by geologists, who in doing so took no special account of soils. While studying both the earth's crust at different depths and the physico-chemical processes in its different parts, the geologists (Sederholm, Becke, van Hise (54)) came to the conclusion that these processes are very dissimilar at various depths, and lead therefore to different results. This fact induced geologists to divide the earth's crust into several zones, among which was instituted the superficial zone of weathering. The physico-chemical processes are manifested in this zone in quite a different way to those of deeper lying zones, and must consequently lead to essentially different results. Soils are wholly included in this superficial zone of weathering.

The recognition of soil, as constituting a distinct natural body, confronted the investigators with a number of problems. To begin with the naturalist was enabled to study the soils from a purely scientific point of view, disregarding all practical consideration. Hitherto the Western European investigator in his studies had always to consider the practical side, being more interested in soils as a subject of importance for the growers of useful plants. This practical point of view handicapped the proper development of science and lead astray scientific thought (135). Having instituted the study of the soil as an independent natural body, Russian scientists beginning with Dokuchaiev had to investigate the properties of the soil and, as it was simpler and easier to study its exterior features, i.e. its morphology, their attention was first drawn to that subject. A closer study of the morphology showed that soils possess their own particularities, different from other loose sediments of the earth's surface as also from deep sea deposits. The aspect of soil as seen in vertical profile was since called its "construction" (profile characteristics), and the study of the latter became the duty of every pedologist. Thus, a great quantity of data on the morphology of soils was accumulated by the Russian searchers in soil science, whereas their colleagues of Western Europe and America were furnished with very little information of that kind. Morphological investigations have enabled Russian pedologists to distinguish more exactly one type of soil from another in the conditions of nature, and have thereby contributed to a more precise knowledge of the geography and the topography of Russian soils.[1] From the study of the morphology of soils they also came to the conclusion that every soil consists of several separate horizons, following one another in a vertical direction, and united by a common origin (genesis). That is the reason why soils may be distinguished from loose sediments mechanically deposited, since the

[1] It would be difficult to enumerate here all the Russian works concerning morphology or construction of soils, as such data can be found in all the papers on local soil and physico-geographical conditions. The works of K. D. Glinka, G. Tumin, and G. Vysotski, treat this question more especially (see Bibliography, Nos. 36, 113–116, 123–126).

different parts of the latter usually possess no genetic relationship which would unite them into one chemico-biological body.

The dissimilarity in the different horizons of the same soil and in the soils of different geographical areas induced Russian scientists to find the cause of this phenomenon. The most striking difference was that of the coloring, and since the coloring of our soils chiefly depends on the presence in them of organic matter—humus—researches were primarily directed towards the determination of the quantity of humus in the soils of different climatic zones. These researches exhibited the existence of a certain definite order in the quantitative distribution of humus on the territory of our country, which enabled Dokuchaiev to establish for the European part the so called "isohumus belts." They were marked on the map, and the position of these belts proved to correspond more or less with the distribution of the soil zones. The term "soil zones," however, was not known at that time. The theory of soil zones, systematized by a pupil of V. V. Dokuchaiev—N. M. Sibirtsev (100, 101), was applied not only to our country, but to all the world. Dokuchaiev himself turned his attention to this question at the end of his scientific career, when he made an attempt of a synthesis of the zonal phenomena in Nature in general; to this attempt we shall return later.

Further on, the study of the "construction" of soils showed that the distribution of humus in one and the same soil profile is also subject to certain laws, and has a different aspect in different types of soil (8, 68, 113–116).

It is, however, evident that the determination of the quantity of humus in the soil was in itself insufficient to obtain a complete notion of any given soil. It had further to be ascertained, on the basis of Dokuchaiev's principles, that its quality differs in various soils. Admitting that such was the case, Dokuchaiev and Sibirtsev, assisted by their pupils (50, 70, 80), made some attempts of approaching the solution of this question, but could get no satisfactory answer, notwithstanding that the above assumption was being confirmed by researches.

This failure is intelligible since the study of the chemical composition of humus, owing to the exceptional complexity of that organic substance, for a long time gave no satisfactory results; such a famous French chemist as Berthelot was baffled in this matter. Only lately since new methods for the study of such organic substances as proteïds were instituted, it was possible to come nearer to the study of the chemical composition of humus in soils. Such attempts were made partly by Japanese, but principally by American scientists; however, it is only fair to mention that some of the questions relating to the chemical nature of humus have been solved by Russian scientists. G. G. Gustavson (51) predicted the existence of hydroxycarboxylic (phenolic) acids in the humus complex, and A. G. Doiarenko (15) that of amids and amino-acids (see also Berthelot).

Trusov (112) tried to explain the chemical composition of humus by the study of such groups of organic compounds which form the so called "humic acid."

Lately A. Schmuck (98) has treated the question of the chemical composition of humus (60).

The American investigators of humus, however, to whom the ideas of Dokuchaiev and the Russian school of soil science were foreign, on having established the nature of several chemical compounds entering into the organic complex of soil, were not interested and probably will never be in the question: of what geographical types and subtypes of soils is any given chemical compound of humus characteristic; this question remains to be solved by Russian soil scientists. The first attempt in this direction showed that the Russian pedologist will undoubtedly find in this matter a confirmation of the fundamental principles of Russian soil science.

The soil, however, does not consist of organic matter alone. The latter plays a very important part in the soil, but its quantity is not great. The mineral compounds vastly predominate, and it is therefore evident that this circumstance had to be considered. The question was treated somewhat differently in Russia than it was by the great majority of West European scientists, since it was very soon discovered that, as the soil consists of several genetically connected horizons, a chemical investigation of one separate horizon would be inadequate for the purpose; a comparatively full knowledge of the chemical nature of soils can only be obtained by investigating the chemical composition of every horizon of a soil including the parent rock. For only thus could the nature of the processes, modifying the parent rock in its transformation into soil and the development of these changes in each horizon, be understood. This method was also sometimes resorted to in Western Europe, but merely in such cases when the difference between the separate horizons of a soil was very striking, as for instance, in the case of podsolized soils containing ortstein. Employing the usual methods of chemical analysis (bulk analysis, water extracts, hydrochloric acid extracts), the Russian pedologist came to know many of the types and subtypes of our soils from the chemical side, and ascertained the chemical character of every separate soil type (i.e. of the podsols, chernozems, alkali-soils, salines, etc.), but with this he was not satisfied. Such chemical researches could not answer the question: what minerals does the soil consist of, and what compounds are characteristic of the soil, in general, and of every type of soil, in particular. Basing himself on Dokuchaiev's fundamental principles, his Russian follower was bound to recognize that, if the soil be a distinct natural body, the reactions taking place in it must be peculiar, and must lead to the formation of compounds, typical of soils only, or of the zone of weathering. These reactions at the same time cannot be typical of the deeper parts of the earth's crust.

Thanks to the work of the microbiologists (bacteriologists), the reactions occurring in the organic part of soils became known to the soil scientist. The leading place in connection with this subject should justly be assigned to the Russian scientist S. N. Vinogradski. We are indebted to him for the explanation of the following processes: nitrification, fixation of nitrogen, oxidation of sulfur and of iron compounds. His pupil, V. L. Omelianski, gave a full account of the decomposition of cellulose. Thanks to these and other similar works, the conclusion was reached that the final decomposition of the organic matter,[1] by means of the activity of microorganisms, leads to its mineralization, i.e. to the formation of ordinary salts (of carbonic, sulfuric, nitric, hydrochloric and phosphoric acids); these salts the pedologist finds on the surface and in the vertical profiles of the steppe and arid steppe soils.[2] Consequently, the conclusion could be made that ordinary salts were one of the typical results of the processes of soil formation, but it was also ascertained that this was not the only result, the processes of soil formation evidently leading also to the formation of other compounds, not found in the deeper zones of the earth's crust.

The foreign pedologist had suggested to his Russian colleague, so long ago as in the fifties of the nineteenth century, that zeolites and zeolite-like minerals are typical, as being the result of the processes of soil formation, and this point of view was supported by Russian pedologists for quite a long period of time, and by some of them even yet. However, in studying the works of the soil specialists of Western Europe, treating of this question, it is easy to see that they do not offer adequate proofs of the existence of zeolite-like compounds in soils. The formation of zeolites and similar complex could likewise not have been expected to occur in the same medium, in which other silicates and alumosilicates, much more stable than zeolites, lose their bases under the influence of weathering. At present we could find support in our point of view on zeolites in the works of Weinschenk, Pelikan, Hübsch and others, who consider zeolites as post-volcanic products. But the supporters of the zeolitic theory state on the contrary that zeolites, found in soils, are not crystalline, but amorphous, so called colloidal zeolites.[3] Though the importance of colloidal sub-

[1] The works of P. S. Kostychev, P. Kossovich, and Tretiakov, S. P. Kravkov and A. Trusov are treating the question of the conditions of the decomposition of organic matter and the dependence of the decay-energy from outward (temperature, moisture), as well as inward (chemical character of the medium) circumstances (see Bibliography, Nos. 65, 69, 74, 75).

[2] A great work of P. S. Kossovich is dedicated to the question of the circulation of chlorine and sulfur [see Communications of the Bureau of Agriculture and Soil Science. Scientific Committee of the Department of Agriculture. Communication XII, St. Petersburg, 1913 (Russian)].

[3] See, for instance: Gedroiz, K. K. The electrolytic action on silty suspensions. Bureau of Agriculture and Soil Science. Scientific Committee of the Department of Agriculture. Communication XXIV, St. Petersburg, 1915 (Russian).

stances in soils is very great, but the quantity of colloidally soluble matter in soil, according to K. K. Gedroiz (29), is scarce, and the greater part of it belongs to the organic part of the soil. One can speak perhaps of "absorption-compounds" in the meaning van Bemmelen (2) gave to them, these compounds being formed through the mutual interaction of the finest suspensions in soil with the solutions circulating therein, but such compounds should not be called zeolites. Admitting the existence of these easily transportable complexes in soil, moreover, continually changing their composition, we have not exhausted all the peculiar groups of substances which serve to separate soils from other loose sediments, not belonging to the zone of weathering.

From the studying of the phenomena of weathering, it was since long possible to assert that complex silicates and alumosilicates of the parent rock, when weathered, easily lose their iron and manganese, those elements appearing later in the products of weathering in the form of different hydrates. In certain not yet sufficiently well defined conditions alumosilicates also lose their alumina which in such cases appears similarly in the form of hydrate (in tropical soils). Thus, another group of compounds, characteristic of the zone of weathering, is formed: hydrates of iron, aluminium and manganese, as should be expected since oxygen and water are the principal factors of weathering. Likewise it is known that different kinds of clay—kaoline,[1] anauxite, halloisite, and others, are typical products of weathering of the largest number of alumosilicates; but few scientists knew all the different phases that an alumosilicate, being weathered, had to pass through until its final transformation into kaoline or into some other complex alumino-silicic acid. By the majority of scientific workers it was supposed that feldspar, for instance, being weathered, was transformed without intermediate stages into kaoline and an alkaline silicate.

The Russian scientist (37) was able to prove on a number of examples from the group of feldspars, mica, augites and zeolites that the process of weathering of alumosilicates is widely different. Every alumosilicate which is chemically a neutral salt of the alumo-silicic acid, while being transformed into the free acid, passes through many intermediate phases, in the form of acid salts. Consequently, one of the typical reactions of soil formation is hydrolysis, and the group of acid salts, continually changing their composition, is one of the typical groups of the zone of weathering. These particular acid salts were later called by A. E. Fersman, Member of the Academy of Sciences (28)—*mutable* compounds.

Ordinary silicates (salts of the silicic acid) also pass through a series of phases—acid salts—and after many a slow and gradual transformation the

[1] For a summary of data on kaoline, see: Ginsburg. I. Kaoline and its origin. Bulletin of the Polytechnical Institute of St. Petersburg, 1912, vol. XVII. Section of Technology, Natural History and Mathematics (Russian).

silicic acid alone remains as the final product; on the earth's surface it is generally found in the form of quartz. Quartz is also the product of weathering of complex alumosilicates, possessing an orthosilicate in their side-chain; such is biotite, for example, the composition of which may be represented by the following formula:

$$[K,H)_2(Al, Fe)_2Si_2O_8(Mg, Fe)_2]SiO_4.$$

The alumino-silicic nucleus of this very complicated mineral gives as a final product kaoline and the orthosilicic nucleus—quartz. Thus, the secondary quartz can also be one of the minerals of weathering. Titanates, as it seems, weather in a similar manner, giving titanic acid as final product in the form of rutile. The fine needles of the latter have often been found in kaoline, these needles being a product of weathering of biotites containing titanium.

The mutable compounds accompany not only the processes of weathering of silicates and alumosilicates, but also those of the decomposition of some complex salts, as phosphates of iron, for instance. S. P. Popov (94), studying the products of weathering of the paravivianit of Kerch $[(Fe, Mn, Ca, Mg)_3(PO_4)_2.8H_2O]$, differentiated among them the following phases of gradual oxidation:

$RO.Fe_2O_3.P_2O_5.7H_2O$—α-kerchenit
$5RO.2Fe_2O_3.3P_2O_5.23H_2O$—$\beta$-kerchenit
$RO.4Fe_2O_3.3P_2O_5.21H_2O$—oxykerchenit
$3Fe_2O_3.P_2O_5.17H_2O$—beraunit.

This example proves that not only the products of hydration (the addition of hydrogen to the composition of weathered minerals), but also those of oxidation (the addition of oxygen) give a series of mutable compounds.

The above mentioned colloidal complexes in soils and all the organic substances of soils, being even more mutable—the conclusion may be drawn that mutable compounds prevail in soils. At the same time soils contain some final products of decomposition, incapable of further change on the earth's surface, such as quartz, rutile, and the like.

In connection with the principle of the peculiarity of soils as natural bodies V. I. Vernadski (119), Member of the Academy of Sciences, thought very probable the accumulation in soils of elements not generally typical of rocks, but characteristic of the zone of weathering. Vernadski considered these elements to be: P, Ti, C, N, Mn, V, F, U, Th—elements of the yttrium and cerium group—as well as Zr and Li. Later, this author gave a more detailed summary of our knowledge referring to this question.

Returning to the connection between climate and soils, it is necessary to point out that the influence of moisture on soils is much more evident than that of temperature. The true statement of G. N. Vysotski (127)

that "water in the soil is as blood in the veins," explains why Russian pedologists were always interested in the question of moisture in soils. Many works were devoted to this question, among which we may mention the works of the following authors: A. A. Izmailski (57), Prof. Golovkinski (46), G. Bliznin (6), Speranski and Krasheninnikov (104), and the very interesting works of A. F. Lebedeff (78), G. F. Morozov (83), G. N. Vysotski (127, 129), E. I. Oppokov (88, 89), G. Liuboslavski (81), F. I. Ziebold (143), P. S. Kossovich (63), P. V. Ototski (90, 91), N. A. Kachinski (58).

As is generally known, foreign scientists established two different points of view on the origin of water in soils and of ground-water: one group connected the origin of ground-waters with atmospheric precipitation, the other considered ground-waters to be the product of condensation of vapor in soils. The last point of view met with serious opposition on the part of Western Europe, and was finally dropped. Russian investigators since revived this theory, although not in the exceptional sense adopted by Folger and his followers, but by placing it on much firmer ground (Ototski, Lebedeff). G. F. Morozov and G. N. Vysotski especially, studied the question of the relation between the moisture of soils and the character of vegetation, whereby, thanks to the works of these two authors, the negative influence of forests on the moisture of the deep horizons of soils was first established.

A great many investigations on the influence of forest growth on the level of ground-water were made by P. V. Ototski, partly by way of observation taken during excursions in different regions of our country, and partly by organizing stationary researches on the variation of the level of ground-water under forests and open spaces. These observations brought the author to the conclusion that the ground-waters under forests on plains are always found at a lower level than waters under neighboring open spaces of the same geological character. Such results, met in Western Europe at first with mistrust, were, however, finally fully accepted; the forest stations in Germany, Austria and Switzerland worked out a program for the study of the influence of forest growth on the régime of ground-waters; the investigations of Prof. Henry (52) in France confirmed the view of Ototski. These views were subsequently confirmed by R. S. Pearson (93) for the neighborhood of Godra in India (district Panch Mahals); thus, the principle established by Ototski for forests on the plains of temperate latitudes, proved to be correct for the tropics as well.

Water, coming into contact with the soil, deprives it of organic, as well as of mineral elements, and dissolves its salts, forming soil solutions. The composition of soil solutions had been studied by West European and American scientists, but it was with Russian searchers that originated the idea, according to which these solutions in soils of different climatic zones are necessarily unlike each other. Consequently, they tried to analyze the difference between solutions circulating in podsolized soils and

in chernozems, in chestnut loams, in alkali-soils, etc., and finally put the question: would it not be possible to use the data relating to soil solutions for the characterization of different types of soil formation (31, 137).

Colloidal chemistry having arisen in Western Europe, and after attempts had been made of applying it to soil science, Russian investigators took their share in the further study of these questions, adopting the position so natural to them as followers of Dokuchaiev's principles. In a series of works of K. K. Gedroiz (30, 32, 33) we meet with attempts to explain the origin and some of the chemical properties of different soil types, as podsols, laterites and especially alkali-soils, based on the peculiarities of their colloids.

It is necessary to add that the influence of the same fundamental ideas which inspire the works of Russian pedologists in all the other problems of soil science, is displayed in the different soil classifications worked out by them. Contrary to the majority of foreign soil scientists, Russian pedologists choose *the soil type* as a unit of classification instead of soil masses, regarding the soil type as a summary of the external and internal properties of a soil. These properties being, as clearly demonstrated above, the result of an interrelation of definite conditions affecting the development of any one soil type, it is evident that every soil type was regarded by the Russian pedologist as a physico-geographical object, having its definite place on the earth's surface, as well as a separate natural body with a series of properties solely belonging to it. Thus, speaking of chernozem, for instance, the Russian pedologist saw not only a natural body with definite properties, but also its geographical position and surroundings, i.e., climate, vegetation and animal life. Consequently, all Russian soil classifications (21–23, 42, 43, 64, 101, 102) are *geographical*, as well as *genetic*, as they are usually called.

The importance of the fundamental ideas of Dokuchaiev in Russian soil science is sufficiently evident from this short account. However, it would not be complete, if we did not enter into the details of the purely geographical aspects of Russian soil science, and did not call more attention to the influence the development of soil science in our country had on other branches of natural history.

As already stated above, the soil zones theory was systematized by Sibirtsev. Many soils, according to this author, "generally have a zonal distribution over the surface of the continents, corresponding to geographical territorial regions. In the general scheme laterite soils occupy the most equatorial position, and correspond with the continental tropical regions zone frequently interrupted by the sea. North and partly south of the tropics, in the region of continental plateaus, and closed and semiclosed plains, lie the loess soils and arid steppe soils; further, on open grass-plains—soils of the chernozem type subsequently merging into forest-podsolized ones and, finally, into tundra-soils."

"Europe and Asia and, partly, North America, are the most typical continents in this respect. The zonality of soils, of course, must be regarded as but an approximate, general scheme. As a matter of fact, not a single soil type extends over a continent in an uninterrupted belt: they are all disposed in the form of belts of different width, either spreading over vast spaces, or narrowing down and mingling with neighboring ones, or finally, forming islands, remote from the principal zone. The completeness and the proper succession of the soil types is broken by local oro-hydrographical and geological peculiarities, hindering the development of certain soils or setting them aside."

Subsequently, it appeared that our soil zones can be subdivided into *subzones*, stretched out in the same direction as the zones on vast areas (25, 26, 45, 99, 113); at the same time it was deemed necessary to establish the so-called soil provinces. As an example of a soil province, we may mention the region of the Precaucasian chernozem and of the Azov chernozem. This region forms an island, wholly isolated in its eastern part from the European-Asiatic chernozem zone and covered by soils, sufficiently unique in their morphology (56, 96, 122, 134).

Studying the soil zones, it was possible to ascertain a certain dependence of the distribution of the soils of neighboring zones upon the elements of the relief, which is manifested in the transition of one zone into another (117).

The Russian pedologist, however, did not confine himself to the establishment of soil zones, subzones and soil provinces. Appreciating the fluctuations of the relief between the limits of every zone, he was called to pay attention to the topography of the soils of one and the same zone, whereby he found that noticeable changes in the character of soils are produced not only by comparatively important elevations and depressions of the surface (macro-relief), but also by almost unnoticeable changes in the features of the relief (micro-relief).

The connection between micro-relief and soils was first manifested during the investigation of the arid steppes; and as a consequence the idea of the soil complexes (5, 7, 14),[1] i.e., of necessary correlation between the micro-relief elements and those of the extremely diversified soil covering (118, 130).

Later, during the investigations of the soils of Siberia, organized by the former Colonization Bureau, it was proved that peculiar soil complexes—combinations of soils—are characteristic of every zone or subzone. This enabled the Russian pedologist to assign a certain territory to some definite soil zone by means of separate elements of the soil covering (26, 61).

[1] Many data may be found in the Transactions of Soil and Botanical Expeditions. Soil investigations, edited by K. D. Glinka (see the works of Tumin, Abutkov, Stasevich, Khainski, and others).

Simultaneously with the development in the study of horizontal soil zones, the idea of vertical zones progressed, i.e., the idea of orderly changes in soils observed in a gradual ascent from the plain to the summits of mountain-ridges. The phenomenon of vertical zonality of local soils was already noticed during the investigation carried out by A. N. Krasnov (72, 73) in the Tian-Shan mountains. Dokuchaiev, in 1898, stated (24) that the existence of vertical soil zones in Nature, according to his words, was "so evident to him, that many years ago, on the basis of one or two facts only he did not hesitate to express the idea of the existence of a vertically-zonal distribution of soils around the ancient Aralo-Caspian basin" . . . The study of the vertical zones of the Caucasus was initiated by Dokuchaiev, but more detailed investigations were carried out by S. A. Zakharov (139–141). The phenomenon of vertical zonality in the Altai mountains, in the high regions of Turkestan and Siberia, and in the Transbaikalian region especially,[1] was more or less fully studied by the pedological expeditions of the former Colonization Bureau. The orderly changes in the disposition of the horizontal soil zones of Kazakstan, due to their approximation to the Altai mountain region, have been equally ascertained by the works of the same expeditions. In pursuing the study of the geography of soils, the Russian pedologist was aware of the close connection existing between the phenomena of soil-geography and those of geobotany and even zoogeography. Thus, he perceived the grand synthesis of Natural Science which is lately beginning to find its expression in the theory of geographical "landscapes."

So long ago as in 1898 Dokuchaiev (24) wrote that "the greatest and highest charm of natural history," "the kernel of natural philosophy," consists in the "existence of an eternal genetic and ever orderly connection between the vegetable, animal and mineral kingdoms on one side, and man, his life and even his spiritual world, on the other." It is true that so far back as 1804 Alexander von Humboldt (55) pointed out a similar connection, although totally excluding the mineral covering of the earth —its epidermis—from the chain of intrinsically connected objects and phenomena, considering this mineral covering to be incapable of orderly distribution in space, as this is the case with living organism.

"It seems to us," wrote Dokuchaiev in the above quoted work, that "soil science, taken in the Russian sense, must be placed in the center of the theory of the interrelation between living beings and inanimated Nature, between man and the rest of the world, i.e., its organic and mineral part." The works of our scientists have proved that soils and subsoils are a mirror or a clear and true reflection of a conjoint, intimately connected and permanent interaction between the air and the earth (the primary parent rock, unaltered yet by the processes of soil formation, i.e.,

[1] The works of S. S. Neustruev, L. I. Prasolov, A. I. Bezsonov, G. M. Tumin, R. I. Abolin, and others.

the subsoils), on one side, and vegetation, animal life and the age of the land—these eternal factors of soil formation—on the other."

Further, characterizing separate soil zones, Dokuchaiev describes not only the soil, but also the climate, plants, animals, and different features of human life in every zone. This is repeated by him on a grander scale by means of a classification-table attached to another work of his (23).

These ideas of Dokuchaiev could not but have the greatest influence on Russian works referring to other branches of natural science: botanical geography, phytosociology, forestry, and partly to zoogeógraphy and geography, in general. As a matter of fact, we can see the influence of principles in a series of works of the following authors: G. I. Tanfiliev, A. N. Krasnov, A. I. Gordiagin, N. I. Kuznetsov, P. N. Krylov, B. A. Keller, V. N. Sukachev (with his pupils), G. N. Vysotski, G. F. Morozov, V. A. Dubianski, and of many other Russian botanists and forest specialists. The present day phytosociologist begins to pay an increasing attention to the geography and topography of soils, more and more frequently finding a connection between soils and vegetation.

"The quantity of information relating to forestry, greatly exceeding that concerning any other types of vegetation, has enabled G. F. Morozov (84) to create a quite independent theory, established by him, on the forest, as a separate 'social organism.' This theory gave a solid footing to the new branch of botany, called phytosociology, and has assured the further development of the same" (105).

Acquainting ourselves more closely with the works of Morozov and his pupils, we can notice, how great is the importance attached by the author to the questions of pedology, and how closely soil science is here connected with forestry. "These principles" (Dokuchaiev's),—writes Morozov (85),—"have played a decisive part in my life and endowed my work with such light and gladness, giving so high a moral satisfaction that it is impossible for me to imagine my life without them, Nature has become to me a great Whole which can be understood on the basis of the study of those very facts, the interaction of which forms this great synthesis. True, the facts principally refer to soils, but still it seems to me that no other body or phenomenon in Nature could so obviously establish the great importance of the geographical synthesis" . . .

The influence of Russian soil science on zoogeographical work was less important, though a series of investigations in this branch of science may be mentioned, as standing in close connection with the study of soils. Such are: first, the work of A. A. Silantiev (142), dealing with the study of the life of the rodents and other animals of the steppe region; then the works of A. I. Gordiagin (49). T. P. Gordeiev and N. A. Dimo (13), of V. A. Balz (1) on ants, the work of G. N. Vysotski (130, 131) on earth-worms and insects inhabiting chernozems, the work of N. A. Dimo (12) on Turkestan termites. The above mentioned authors indicate a definite

connection between the activity of animals, the morphology of soils (121) and even their chemical properties, and sometimes vegetation as well (the distribution of the system of roots along the channels excavated by soil animals).

Lately, "landscapes", i.e., synthetical combinations of various natural phenomena (53, 135), are being recognized as the object of geographical research. With Russian geographers the basis of such landscapes will undoubtedly be the soil. According to L. S. Berg (4), "the final aim" of geography "is the study and the description of natural, as well as cultivated landscapes." "Natural landscapes are such, in whose creation man took no part whatever, whereas man's work and the products of his culture play an important rôle in the cultivated ones." The natural landscape is a region, in which the character of the relief, climate, vegetation and soils (in its whole) is regularly repeated within the limits of a certain zone. Thus, the problems of scientific geography can be defined as follows: the study of the causes which tend to combine relief, climate, soils and vegetation into a landscape, as definite in its features as only an organism can be, as well as the investigation of the mutual influences exerted by these different factors. The aforesaid can also be referred to cultivated landscapes.

The same author, in 1913, made an attempt to draw a map of the landscape zones for Russia, based partly on the data collected by the pedological expeditions of the former Colonization Bureau in Siberia (3).

According to another Russian geographer (9), "it would be difficult to overestimate the importance of the knowledge of the soil-covering for the geographer. The soil is the most sensitive index of the slightest modifications of the relief, the amount of moisture of heat, etc.," "the composition and the limits of vegetation of a locality is first determined by soils; the soil is also one of the determining causes of the direction and the intensity of the activity of man (in many stages of his culture)." There can be no doubt that in future the Russian microbiologist will also be obliged to connect his problems with the study of soils; he will have to consider perhaps not so much the geography of the micro-organisms themselves, since they are more cosmopolitan than any other living organism (87), but in any case the geography and topography of the microbiological processes, their energy, the predominance of some processes over others, the suppression of yet others in certain conditions of the medium, and so on. Some facts supporting such a view already exist, but the data are much too scarce as yet for any generalization.

Russian soil science was always closely connected with geology, and attempts were even made to assist, with the help of pedology, that branch of science in the reconstitution of the physico-geographical conditions of previous geological periods. Indeed, if soils at the present time correspond with definite climatic conditions, this statement must also be true

as regards all the geological periods, and therefore the study of ancient and fossil soils (35, 38, 39) should be able to throw some light on the conditions of the geological periods, among the deposits of which the soils are being found, and thereby contribute to the restoration of geographical landscapes of former times.

In this direction most probably much can still be expected from soil science, and we may express the hope, that by means of pedological methods continental formations will be revealed which, in comparison to sea deposits, have as yet been studied much less.

There is, however, one side of soil science, on which much work will still have to be expended by the coming generation of Russian pedologists. So far the soil scientists have principally centered their attention on stationary conditions of soils, and were perfectly right in so doing, as it was most essential first to know what particular soil types and subtypes exist on Russian territory, and how they are distributed over it. Russian soil science now possesses a vast fund of information on this subject. Extensive areas are being investigated not only in the European, but also in the Asiatic parts of the U.S.S.R., and besides schematic maps prepared for the entire Russian territory, many a detailed soil map has been drawn for large areas. It may be stated without exaggeration that the quantity of data Russia disposed of in this respect, cannot be found in any other country of the world. Although that work is not yet finished, and there still remains much to be done in this direction, the Russian pedologist already feels that he cannot confine himself to the study of the statics of soils, but that he will be obliged to commence studying the dynamics or the life of soils as well.[1] The connection between soils and climate being known, and the climatic phenomena being periodical, those of the life of soils must be periodical also. This periodical phenomena must be studied, as by means of this study it will be possible to understand more fully the conditions of the genesis of soils and their chemico-biological processes.

Such a study will enable the soil scientist to approach the work of the agriculturist, one of whose problems consists in ascertaining the connection between the properties of a soil and the life of a cultivated plant and the corresponding intervention of man. This intervention can only be rational if the agriculturist will understand clearly, in which direction he is altering the life of a soil. The full understanding of all the processes occuring in a cultivated soil will be possible only when those of a virgin soil be known. At the same time, the study of the dynamics of soil processes or the physiology of soils can be successful, only if it be through-

[1] The following authors must be mentioned, as treating this question: first of all A. G. Doiarenko, with his pupils, then: V. V. Hemmerling, S. P. Kravkov and E. A. Domrachova; researches are made in the same direction by S. I. Tiuremnov (Krasnodar), I. K. Negodnov (Turkestan), M. A. Vinokurov (Omsk), A. I. Lebediantsev (Shatilov Experimental Station), V. P. Illuviev, with assistants (Engelhardt Experimental Station), Kuzmin (Saratov Regional Experimental Station).

out connected with the anatomy of soils, which is one of the immediate conclusions to be drawn from Dokuchaiev's main conception of soils.

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Part of the morning was given over to a motorbus trip about the City of Washington for the ladies after which luncheon was provided at the Congressional Country Club. Mrs. W. W. Skinner was hostess for the occasion.

SPECIAL AND GENERAL SESSIONS

Sixth Day—Saturday, June 18, 1927

The entire day was devoted to special and general sessions of the various commissions, but for those members not so occupied, entertainment was provided by an excursion to Mt. Vernon, the home of George Washington. A visit to the National Cemetery at Arlington was included. The party was joined by the ladies.

SPECIAL SESSIONS OF COMMISSIONS

2: 00 P.M.—The business sessions and programs devoted to presentation of papers were held by the several commissions.

SPECIAL EVENING SESSION

8: 00 P.M.—Chemical and physical investigations, humus, soil dynamics and agronomic investigations were among the subjects discussed in the evening session under the leadership of the Russian delegation.

Seventh Day—Sunday, June 19, 1927

The Congress was adjourned upon this day and the members were dependent upon their own resources.

SPECIAL AND GENERAL SESSIONS

Eighth Day—Monday, June 20, 1927

The entire day was devoted to special meetings of the several commissions and a formal reception at the National Gallery of Art in the evening concluded the activities of the Congress for the day.

During the afternoon the ladies indulged in a shopping tour of Washington's business section.

BALTIMORE EXCURSION

Ninth Day—Tuesday, June 21, 1927

7:00 A.M.—The Willard Hotel was again the point of departure for an excursion and the participants assembled at this hour to take the busses for a trip to Baltimore. The men of the party were given the opportunity to visit the business section of Baltimore and to enjoy a trip down the harbor.

Mrs. R. W. Dunlap, of the Hospitality Committee, arranged a delightful motorbus trip for the ladies attending the Congress. After a visit to the National Naval Academy they joined the men at the University of Maryland in the evening where dinner was provided through the courtesy of the Faculty.

TRIP TO BALTIMORE AND BALTIMORE HARBOR

Ernest H. Bailey

At 7:30 on the morning of June 21, about one hundred and fifty of us left the Willard Hotel in six auto busses for a trip to Baltimore. The ladies attending the Congress, left at the same time in two busses for Annapolis. Our entire trip lay through the Coastal Plain, the soils of which are derived from unconsolidated sediments brought down from the adjoining uplands. Our route first led us southeast from Washington, on the La Plata Road, to the little village of T. B. The soil occupying the broad flat ridges was the Leonardtown silt loam. On the slopes occurred the Susquehanna gravel, the latter being mostly wasteland.

At T. B. we stopped and examined a virgin profile of Leonardtown silt loam, exposed by a roadside cut. Under a very thin layer of dark leaf mold the soil graded into a friable grayish-yellow to pale-yellow silt loam, to a depth of about 7 inches. This constituted the A-horizon.

The B-horizon, which was about a foot in thickness, consisted of a brownish-yellow to a light brown, silty clay loam. It was friable and crumbly, breaking into irregular shaped lumps, about a quarter of an inch in diameter, and finally crumbling down into small particles having somewhat of a nut structure. The lower 2 inches of this layer showed light gray mottlings and was quite waterlogged. Underneath lay the hardpan layer a characteristic feature of this type. Having a thickness of about 18 inches, it consisted of mottled light gray, yellowish to light brown, hard, compact material of fine sand, small rounded gravel, silt and clay. It was very hard and dry and was difficult to penetrate with either a soil auger or a pick. When dug out, it broke into angular blacks and platy fragments, showing somewhat of a laminated structure. The brown coloration occurred mainly along the cleavage lines while the basic color was light gray or yellowish-gray. When the plant roots reached this layer they spread out in a lateral direction showing that it offered a serious obstruction to penetration by them. This hardpan layer also appeared to be almost impervious to water. In consequence of this, Leonardtown soils are cold and waterlogged in the spring and droughty in the late summer. It is said that George Washington learned to swear while farming this soil. Do you wonder? The native vegetation consisted of stunted white oak, scrub pine and sweet gum. Most of the land had been cleared but was lying idle.

From T. B. we took the Crane Highway to the village of Upper Marlboro where the Collington soils are well developed. Near that village we examined a roadside cut of Collington sandy loam. Underneath a thin layer of leaf mold lay a rich brown sandy loam which graded into a light greenish-brown sandy loam at about 10 inches. The B-horizon commenced at about 15 inches— a greenish friable sandy clay, which graded into the soft greenish glauconite, the parent material, at about 2 feet. The glauconite is so soft that it can be shovelled without any difficulty. Most of this soil was under cultivation although this location had a fine growth of white oak, red oak, black oak, and hickory on it. This is a good potato and fruit soil and is also a splendid trucking soil.

SCENE IN BALTIMORE HARBOR

From Upper Marlboro, we drove to Baltimore, arriving there about noon. We went immediately to the Baltimore and Ohio Railway Company's docks where we embarked on one of their steamers for a trip down the harbor. A complimentary lunch was served us on the boat.

On the way we had a good opportunity to observe Baltimore's fine busy water front, crowded with factories and warehouses. Baltimore is the largest fertilizer center in the world. Its factories ship to Canada, to Texas, and to the whole world. We visited the Davison Chemical Company's Phosphate Plant, which is the largest one of its kind in the world. They make their own sulfuric acid and are reputed to have the largest plant for its manufacture, in the industry. There raw rock phosphate, shipped from Florida, was treated with sulfuric acid and converted into readily available acid phosphate. We also visited Swift and Company's fertilizer plant, which mixed the acid phosphate from the Davison plant with potash and nitrogen to make complete fertilizers.

In the outskirts of Baltimore the driver of one of our busses was detained by a minor accident to a little girl who carelessly ran in front of the bus he was driving. Fortunately the child received but a few slight bruises.

Our party reached Maryland University at 7:00 o'clock and here we had dinner, after being joined by the ladies. Dr. Pearson, President of Maryland University, and others, made short after dinner speeches. We arrived at Washington about 11:00 o'clock feeling that we had all spent a very pleasant and profitable day.

SPECIAL SESSIONS OF COMMISSIONS

Tenth Day—Wednesday, June 22, 1927

9:30 A.M.—A few separate meetings of the commissions were held, but most of the morning and part of the afternoon were devoted to the election of officers and presentation of committee reports.

ELECTION OF OFFICERS

Dr. D. J. Hissink, General Secretary, and Dr. M. Trénel, Secretary of Commission III, presented a report of the Congress which details the election of officers and the transaction of business of the final General Session.

PROCEEDINGS OF THE FIRST INTERNATIONAL CONGRESS OF SOIL SCIENCE

Washington, D. C., U. S. A., June 13–22, 1927

Dr. D. J. Hissink, General Secretary
Dr. M. Trénel, Secretary, Commission IV.

A joint meeting of the Executive Committee of the International Society of Soil Science and the American Organizing Committee held Saturday, June 11, 1927, at 10:00 A.M. There are no minutes of this meeting. At this meeting a Special Committee was appointed which was authorized to discuss in the following days various matters pending (by-laws, journal, founding of new commissions, date of the second congress, etc.), in order that appropriate action could be taken in the final general session of the Society on June 22. The following committee was chosen: Dr. Lipman, President; Jarilov, Keen, McCall, Saidel, Schucht, Schreiner, de'Sigmond, Weiss, Wiegner and Hissink. In addition a committee consisting of Stremme, Chairman: Marbut, Glinka, Weiss and Hesselmann was appointed to study particularly the question of forming new commissions.

The following meetings were held:

First meeting of the Special Committee, Sunday, June 12, 1927 at 3:00 P.M.; second meeting, Wednesday, June 15, 1927, at 5:00 P.M. Dr. Hobson, delegate of the International Institute of Agriculture at Rome, and Stremme and Marbut of the Stremme subcommittee, were invited to this last meeting.

Second joint meeting of the Executive Committee and the American Organizing Committee was Friday, June 17, 1927.

Third meeting of the Executive Committee of the Society was Saturday evening, June 18, 1927.

At the two last meetings Trénel and Smolik were present as secretaries.

The General Sessions of the International Society of Soil Science took place:

Monday, June 13, at 2:00 P.M.

Address of the President of the United States, The Hon. Calvin Coolidge.

Response by Dr. Lipman.

Roll-call and addresses of greetings by the official delegates.

Roll-call of scientific societies.

Tuesday, June 14, 1927, 9:30 A.M.

At this session the following reports were rendered:

Report of Dr. D. J. Hissink, Acting President, and General Secretary.

Reports of the presidents of the International Commissions (Novák, de'Sigmond, Waksman, Trénel acting for Mitscherlich, Marbut, Girsberger).

For the addresses at the General Sessions on June 14 and the following days see the program.

Final General Session, Wednesday, June 23, 1927, 2:00 P.M. in the Chamber of Commerce.

President: Dr. Jacob G. Lipman, United States of America
Acting President and General Secretary: Dr. D. J. Hissink, Holland
Secretary: Dr. M. Trénel, Germany

(1) Election of the Executive Committee:

(a) In accordance with the proposal of Dr. Lipman, the following men were elected by secret ballot:

President: Prof. Dr. K. D. Glinka, Leningrad
Acting President: Dr. D. J. Hissink, Groningen
Vice Presidents: Prof. Dr. G. De Angelis d'Ossat, Rome
Dr. Benj. Frosterus, Helsingfors
General Secretary: Dr. D. J. Hissink, Groningen

Since no proposals regarding the Librarian had arrived from the International Institute of Agriculture at Rome, this position could not be filled for the time being. The General Secretary is authorized to take up this matter with the Institute at Rome, whereupon the Executive Committee will take action. It is emphatically asserted that the Society assigns great value to the retention of the center of Soil Science Bibliography in the Institute at Rome.

(1) In conformity with Section 8 of the By-laws, the representative of the International Institute of Agriculture at Rome is appointed by the Institute. Prof. F. Schucht of Berlin continues in office as editor of the Journal.

> (b) The General Committee is composed of the Executive Committee and a number of members elected by the Congress in open vote, as well as of the representatives of the National Sections and the Commissions.
>
> Messrs. Asō, Miklaszewski, Novarese, McCall, Schreiner and Weigner were elected members of the General Committee by acclamation.

Professor Novák reported the recent death of Prof. Dr. G. André, of Paris.

The present membership of the Executive Committee and the General Committee is given in Appendix I.

(2) Location of the Second Congress: In conformity with Section 12 of the By-laws the General Committee, after agreement with the International Institute of Agriculture, determines the place and time of the Congress, in reference to which the wishes of the preceding Congress are to be considered as far as possible. The question as to where the Second Congress was to be held had been considered at the meeting of the General Committee at Groningen, April 7, 1926. It had been decided at that time to propose to the Congress at Washington that the Second Congress be held in Russia. Should Russia not be able to hold the Congress, the General Committee would choose by correspondence between Germany and Poland. The following telegram of June 6, 1927, was received from the Institute at Rome:

> ASHER HOBSON,
> Department of Agriculture,
> Washington, D. C.
>
> Permanent committee leaves Washington decision seat future congress. Please inform Hissink. Greetings.
>
> DRAGONI.

The Congress decided to hold the Second Congress in Russia in 1920. However, about a year in advance, that is in 1929, inquiry shall be made

as to whether this appears possible. Should it not be possible the Executive Committee is empowered to determine the place and date of the Second Congress with the advice of the Institute at Rome.

(3) The Journal: In a letter dated December 28, 1926, the Institute at Rome announced that it could no longer continue the publication and issue of the Journal in the year 1927, under the financial terms fixed for the years 1925 and 1926. A new agreement has already been effected with the Institute for the publication and issue of Part III of the Journal (year 1927). Although the Institute has made the financial terms for the year 1927 as favorable as possible to the Society, nevertheless the sum necessary for Part III (1927) exceeds the financial resources of the Society. However, as the Society possesses a small capital, in consequence of the foundation dues received in 1924, it will be possible to issue Part III in 1927, under the terms agreed upon. For the year 1928, however, other arrangements must be made.

The following proposals of the Executive Committee were adopted: Beginning with the first of January 1928, the Journal will be issued in the form of a Central Organ of Soil Science. The references appear in the language in which they have been sent in, in German, English or French, as the case may be: the titles will be printed in several languages. For the present this Central Organ appears in quarterly numbers of 32 pages each, or 128 pages altogether. For editorial and administrative assistance, fees and for all printing and office expenses, a maximum sum of 6000 marks is placed at the disposal of Prof. Schucht. The publication will be at Berlin.

In addition the American Organizing Committee was asked to place at the disposal of the Society a sum of 1500 dollars, 500 dollars to be available annually. According to Dr. Lipman, Dr. Schreiner, Dr. Marbut and Dr. McCall, members of the Executive Committee of the American Organizing Committee, this sum could be drawn from the interest on the capital of 20,000 dollars available for printing the transactions of the Congress.

It is further assumed that the Society is to appeal to the Governments Societies, Corporations, etc., for assistance.

Finally the Congress expresses to the Institute at Rome its thanks to the latter for having conducted the publication and issue of the Journal under such favorable financial terms. Without the valuable assistance of the Institute the Society would not have been able to survive the first arduous years. It is emphatically voiced that the seat of the Society in the future, as in the past, remain at Rome with the International Institute of Agriculture, and that the bonds between the Institute and Society continue.

(4) Changes in the By-laws: The following changes in the By-laws were adopted:

(a) Section 8. The Executive Committee conducts the business of the Society. It consists of (1), etc. . . . is amended with: (8) "Members ex-officio" and concludes with: "Members ex-officio are the ex-presidents of the Society."

(b) Section 14 is changed to read as follows: "The Journal is issued by the Executive Committee and conducted by the Editor. Printing and publication are attended to by the Editor under the direction of the Executive Committee."

(c) The following is added to Section 16: "Members, who have not paid their dues by the end of the year will be stricken from the list of members."

Through the amendment to the By-laws under (a), Dr. Jacob G. Lipman becomes the first ex-officio member of the Executive Committee.

(5) Finances: Prof. Wiegner submitted the report of the Treasury Auditing Committee consisting of Drs. Jarilov, Schreiner, and Wiegner. Dr. Schreiner translated it into English. The report as read, follows:

WASHINGTON, D. C., June 22, 1927.

Your auditing committee has not been able to see the bills and vouchers, but has examined the financial statement of the Secretary-Treasury, and it appears to be a correct statement of the financial condition of the society.

ARS. JARILOV.
GEORG WIEGNER,
OSWALD SCHREINER,
Auditing Committee.

A survey of the finances is given in Appendix II.

(6) Honorary Members: On the motion of the Executive Committee, Peter Treitz was elected Honorary Member of the International Society of Soil Science by acclamation.

(7) Prof. Weiss of Copenhagen read a letter from the International Society of Soil Science to the Governments of members who had recently died (Murgoci, Ramann, Oesterberg, Müller, Christensen and Andre).

(8) Hissink announced that the Russian exhibit has been presented to the Bureau of Soils at Washington, D. C., U. S. A. The Russian example will be followed by other delegations.

(9) Hissink announced the prices of the publications of the Society appearing up to date, for members of the Society:

(a) Transactions of the Second Commission, Groningen, 1926, Vol. A, and 1927, Vol. B: 2.00 American dollars for both.

(b) Abstracts of the Transactions of the First International Congress of Soil Science, June 13th to 22nd, 1927, Washington,

D. C., U. S. A. 3 volumes: Commissions I and II; Commissions III and IV; Commissions V and VI; 2.00 American dollars for all. For non-members the prices are double.

(c) Members are to receive the Soil Map of Europe as well as the Transactions of the First Commission (Rothamsted 1926) free of cost.

(d) The Transactions of the First Congress at Washington unfortunately cannot be supplied free of cost. However, members of the Society will receive a preferential rate (half of the dealer's price). The price has not yet been fixed.

(10) Re-organization of the Commissions: After much debate, the formation of new commissions and re-organization of present commissions has been refused by the Executive Committee. However, it is left to the discretion of the presidents of the individual commissions to form subcommissions when such are necessary. The proposals of Weiss and others (See Report of Commission VI, subcommission V) are thereby disposed of. The Subcommission for Forest Soils (Prof. F. Weiss, chairman) accordingly belongs to the Fifth Commission; the Subcommission for peat soils (Prof. A. P. Dachnowski-Stokes, chairman) to the Sixth Commission.

Prof. Jarilov has been authorized to prepare the organization of the study of historical soil science.

(11) The reports of the presidents of the individual commissions, regarding the activity and organization of their commissions were submitted. (All have not been received.)

(12) Miller, of the American Organizing Committee, expressed the gratitude of the Society to the following persons and corporations:

Department of Agriculture, Washington
Secretary of Agriculture, Jardine
Lipman, McCall, Hissink
Chamber of Commerce
Pan American Union
National Gallery
The Ladies of the Department of Agriculture
The Exhibitors
The Press, and
The Baltimore and Ohio Railroad.

(13) Dr. McCall made announcements in regard to the transcontinental tour.

(14) A telegram of greeting was sent to Prof. Gedroiz of Leningrad.

(15) The President closed the Session at 4:25 P.M.

Signed: Trénel. Hissink.

THE INTERNATIONAL SOCIETY OF SOIL SCIENCE

Officers for Second Congress *Appendix I*

Honorary Members

Prof. Dr. L. Cayeux, Professeur au Collège de France et à l'Institut national Agronomique. 6, Place Denfert-Rochereau, Paris (14°) (France).

Prof. Dr. K. D. Glinka, Landwirtschaftliches Institut, Tschaikowsky-str. 1. Detskoje Sselo, bei Leningrad (U. S. S. R.).

Prof. Eng. J. Kopécky, Institut agropédologique de l'Etat. Karlovo nám 3. Prague II (Czechoslovakia).

Sir John Russell, Director Rothamsted Experimental Station, Harpenden (England).

Prof. Dr. P. Treitz, K. ung. Agrochefgeologe Oberbergrat, Königl. Ung. Geologische Reichsanstalt. Stefánia-út, 14–16, Budapest, VII (Hungary).

Prof. Dr. S. Winogradsky, Institut Pasteur, Brie-Comte-Robert (Seine et Marne), Paris (France).

General Committee

EXECUTIVE COMMITTEE

President

Prof. Dr. K. D. Glinka [1]
Leningrad (U. S. S. R.)

Acting President

Dr. D. J. Hissink
Herman Colleniusstraat 25, Groningen (Holland)

Vice Presidents

Prof. Dr. G. De Angelis d'Ossat
Via Calatafimi 21, Rome (21) (Italy)

Dr. B Frosterus
Staatliches' Bodenuntersuchungsinstitut, Boulevardsgatan 29, Helsinsfors (Finland)

Representative of the International Institute of Agriculture in Rome

Eng. Fr. Bilbao y Sevilla
Délégué de l'Espagne dans l'Institut International d'Agriculture, Villa Umberto I, Roma (10) (Italy)

[1] Since the death of Dr. Glinka, Dr. K. K. Gedroiz has been appointed as President.

General Secretary

Dr. D. J. Hissink
Groningen (Holland)

Editor of the Journal

Prof. Dr. F. Schucht
Güntzelstrass, 59, Berlin, Wilmersdorf (Germany)

Librarian

Appointment pending

Member Ex-officio

Dr. J. G. Lipman
Experiment Station, New Brunswick, N. J. (U. S. A.)

ELECTED MEMBERS

Prof. Dr. K. Asō, Agricultural Chemical Laboratory, Komaba, Tokyo (Japan)

Prof. Dr. fil. H. Hesselman, Djursholm (Sweden)

Dr. A. G. McCall, Room 112, Department of Agriculture, Washington, D. C. (U. S. A.)

Dr. S. Miklaszewski, Rue Szopena 6. Varsovie (Poland)

Prof. L. Novarese (Italy)

Dr. O. Schreiner, Department of Agriculture, Washington, D. C. (U. S. A.)

Prof. Dr. Wiegner, Adlisbergstrasse 92, (Universitätsstr. 2) Zürich (Switzerland)

THE PRESIDENTS OF THE SIX INTERNATIONAL COMMISSIONS.

I. Prof. Dr. V. Novák, Chef de l'Institut Pédologique, Květná 19. Brno (Czechoslovakia)

II. Prof. Dr. A. A. J. de'Sigmond, Chemische Landesanstalt, Kelet Károly u. 24, Budapest, II (Hungary)

III. Prof. V. L. Omelianski, Leningrad (U. S. S. R.)

IV. Prof. Dr. E. A. Mitscherlich, Planzenbau-Institut der Universität. Tragheimerkirchenstr. 72. Königsberg i. Pr. (Germany)

V. Prof. Dr. K. D. Glinka, Tschajkowsky str., Leningrad (U. S. S. R.)

Subcommission for Soil Mapping

Europe: Prof. Dr. H. Stremme, Neptunstrasse, 14. Danzig (Germany)

America: Prof. Dr. C. F. Marbut, United States Department of Agriculture, Washington, D. C. (U. S. A.)

Asia: Prof. Dr. S. Neustruev, Mytninskaya naberegnaya 9. log. 2., Leningrad (U. S. S. R.)

Subcommission on Forest Soils

Prof. Dr. F. Weiss, København (Denmark)

VI. Ing. J. Girsberger, Kultur-Obergenieur, Kaspar Escherhaus, Zürich I (Switzerland)

Subcommission on Peat Soils

Dr. A. P. Dachnowski-Stokes, United States Department of Agriculture, Washington, D. C. (U. S. A.)

Representatives of the National Sections

Dr. B. Aarnio, Staatliches Bodenuntersuchungsinstitut, Bulevardinkatu 29, Helsinki (Finland)

Prof. Dr. K. O. Björlykke, Aas (Norway)

Prof. J. Hendrick, Marischal College, Harpenden (England)

Prof. Dr. A. A. Jarilov, Wosdwijenka 5, Gosplan, Moskau (U. S. S. R.)

Prof. Ing. Kopécky, Institut agropédologique de l'Etat, Karlove nám 3, Prague, II (Czechslovakia)

Prof. Dr. O. Lemmermann, Direktor des Instituts für Agriculturchemie und Bakteriologie der Landwirtschaftlichen, Hochschule, Albrecht-Thaerweg 1. Berlin, Dahlem (Germany)

Prof. Dr. T. Saidel, Chimiste-chef à l'Institute Géologique de Roumanie, Séction Agrogéologique, Soseaua Ardealului (Kiselef) 2. Bucuresti (Rumania)

Prof. Dr. P. Treitz, K. ung. Agrochefgeologe Oberbergrat, Königl. Ung. Geologische Reichsanstalt, Stefania-ut 14–16, Budapest, VII (Hungary)

Prof. Dr. F. Weiss, Director: Den kgl. Veterinaer-og Landbohøjskoles plantefysiologiske Laboratorium. Rolighedsvej 23. København V (Denmark)

Prof. Dr. J. T. White, Hoofd van het Lab. voor Bodenk. Onderz. v/h Algemeen Proefstation voor den Landvouw. Buitenzorg (Java)

INTERNATIONAL SOCIETY OF SOIL SCIENCE

Statement of Accounts

Appendix II

Received as of May 20, 1927:		
Members (1924–'25–'26–'27)	f. 18,060.34	
Contribution of the Czechoslovakian Government	72.75	
Received for the Reports of the Fourth Conference (Rome 1924)	209.20	
		f. 18,342.29
Expenses up to January 1, 1926:		
See Proceedings of the Intern. Society of Soil Science, N. S., II, 1926, No. 2	4,937.29	
Expenses at Groningen, 1926:		
(Secretary's office):		
Printing, etc.	f. 230.90	
Miscellaneous	45.70	
Stamps	269.17	
Secretarial expenses	361.49	
Cost of translations	201.30	
		f. 1,108.56
Other expenses, 1926:		
Stamps, Expedition Volume A	f. 285.88	
Meeting of the General Committee, April 7, 1926, Groningen	202.10	
Cost, journeys General Committee	215.00	
First Commission	75.35	
		f. 6,824.18
		f. 11,518.11

Groningen, May 1927.

(Signed) D. J. Hissink.

COMMITTEE REPORTS

Following the general secretary's report, the chairman, Dr. Lipman, of the Special Committee, referred to in Dr. Hissink's report, presented the minutes of their meeting.

SPECIAL COMMITTEE MEETING

June 12, 1927

Mr. Chairman, Ladies and Gentlemen: The first meeting of the Special Committee of the First International Congress of Soil Science, was held Sunday June 12, 1927, 3 P.M., at the New Willard Hotel, Washington, D. C., United States of America.

Those present were Dr. Lipman, Chairman; Prof. de'Sigmond, Prof. Weiss, Prof. Jarilov, Dr. McCall, Dr. Keen, Prof. Schucht, Prof. Wiegner, Dr. Schreiner, Dr. Hissink.

(1) Increase in Committee

The question as to whether the committee should be increased by the addition of several members was answered by "no."

(2) Journal

Prof. Schucht explained that the cost of issuing a Central Organ with abstracts (references) on soil science, with a total of 128 pages, and 1000 copies, would amount to approximately 4500–5000 marks, including fees, office expenses (forwarding expenses) and administrative assistance. Prof. Schucht further announced that, on account of being overburdened with other work, he must ask for release as editor, beginning with January 1st.

The abstracts will appear only in the language in which they are sent in; the titles will be given in several languages. Naturally it is to be recommended that the abstracts be submitted in only the three languages; English, German and French.

Finally, if the finances permit it, supplements on special subjects could be published.

The question as to whether Prof. Schucht was prepared to continue as editor, if editorial assistance were made available, was answered in the affirmative by Prof. Schucht.

Dr. Hissink now gave the following review of the receipts and expenditures of the Society. Per member, about f. 6.00 of the annual dues of f. 6.50 are received. The expenses of the Secretary's Office and the Com-

missions amount to at least f. 2500.00; the expenses of the new Central Organ without editorial assistance approximates 5000 marks, and 1000 marks for assistance would total 6000 marks; equivalent to about f. 3600.00. Altogether about f. 2500.00 and f. 3600.00—totalling f. 6100.00. Thus, if the Society had 1000 members the receipts will be sufficient to cover the expenditures. However, there is then no sum available to the Society for unforseen expenses. Furthermore, the Society does not have 1000 members. A contribution would thus be necessary, which is estimated to be approximately f. 1250, or $500.00. The question now is, whether the American Committee is ready and in a position to place at the disposal of the Society, for three years (that is until the next Congress) a sum of $500.00 annually, or f. 1500.00.

It was decided to make the following proposal to the Congress:

Beginning with the first of January, 1928, the Journal will be issued in the form of a Central Organ for Soil Science. The abstracts will appear in the language in which they are submitted, preferably in German, English or French; the titles will be given in several languages.

For the present this Central Organ will appear in quarterly numbers of 32 pages each, altogether 128 pages.

For editorial assistance, administrative assistance, fees, and for all printing and forwarding expenses, an allowance of a maximum of 6000 marks will be placed at Prof. Schucht's disposal. The printing will be done in Berlin.

The American Organizing Committee will be asked to place at the disposal of the Society a contribution of $500.00 annually for three years. In the opinion of Dr. Lipman, Dr. Schreiner and Dr. McCall, this amount could be withdrawn from the interest on the fund of $20,000, which is available for publishing the transactions of the Congress.

It was further proposed that the Society appeal to the governments, societies, corporations, etc. for assistance.

If the Congress declares itself in agreement with the proposal concerning the issue of the Journal, paragraph 14 of the By-laws must be correspondingly altered, as follows: From January 1st, 1928, the publication of the Journal will be transferred to the General Committee.

It was emphatically asserted that the International Institute of Agriculture at Rome is invited to this Congress and to the meetings of the General Committee: that furthermore they have been asked several times for proposals concerning the further publication of the Journal for 1928 and succeeding years; that however no proposals have yet been received. Nevertheless, Prof. Perioni, representative of the National Section of Italy, shall be consulted.

Finally it was decided that a committee (Lipman, Schucht and Hissink) shall get in touch with the University at New Brunswick to determine to what extent it would be possible for the journal "Soil Science"

to cooperate in the future with the International Society and also whether they would accept papers in other languages.

Concerning the matter of Librarian Borgherani, it was decided to ask the Institute once more for definite proposals pertaining hereto: if these are not submitted, the matter will be referred to the General Committee for action.

In regard to the Second Congress, a telegram from the Institute (Rome) was read by Dr. Lipman, to the effect that Rome declared itself in agreement with the choice of the Congress.

Prof. Jarilov then announced that it is the prevailing opinion that the invitation for participation in the Second International Congress is to be extended by the Academy of Sciences and the Pedological Society of Russia; furthermore he gave renewed assurance that Russia could provide for the Congress. The following decision was made: The members of the General Committee present will propose to the Congress that the Second Congress be held in Russia, with the condition, that sufficient assurance as to the attendance could be given at an early date. Should this not be possible the General Committee, in conformity with paragraph 12 of the By-laws will select another country.

In regard to honorary members, on the motion of Prof. Stremme and Prof. Schucht it was decided to propose to the Congress the name of Peter Treitz, of Budapest, for Honorary Member.

In reference to the letter of Dr. Doerell it was agreed that proposals for the election of honorary members must be signed by at least three, non-interested members.

Sir John Russell, Chairman of the Resolutions Committee presented the following report for the committee:

REPORT OF THE COMMITTEE ON RESOLUTIONS OF THE FIRST INTERNATIONAL CONGRESS OF SOIL SCIENCE

The Resolutions Committee of the First International Congress of Soil Science, in session in Washington, D. C., wishes to submit the following resolutions and recommends their adoption:

First, we wish to express to the Honorable Secretary of Agriculture, William M. Jardine, and his able staff in the United States Department of Agriculture our deep appreciation for the many courtesies extended to the entire membership throughout the period of the Congress.

Second, in view of the fact that the noteworthy success of this Congress has been largely due to the earnest and sustained efforts of our honored president Dr. J. G. Lipman, who has given so freely of his time and thought, and who almost unaided has made possible the financing of the program of the Congress including the extended transcontinental tour,

we hereby record our very great indebtedness to Dr. Lipman for his outstanding services.

Third, we wish also to express our indebtedness to the Secretary-Treasurer, Dr. D. J. Hissink, and to the Executive Secretary Dr. A. G. McCall for their very efficient services and their untiring efforts in arranging and carrying through the program of the Congress.

Fourth, we wish to further express to the Chamber of Commerce of the United States our thanks for the splendid facilities provided in the Washington building for the meetings and exhibits of their Congress.

Fifth, since a very large measure of the success of the Congress has been due directly to the generous contributions made by a large number of individuals and organizations, the members of this Congress wish to record their deep appreciation for this liberal support.

Sixth, we wish also to indicate our obligations to the officials of the Pan American Union and the National Gallery of Art for the use of their buildings on the occasion of two of the most enjoyable social functions of the Congress.

Seventh, we wish to express our gratitude to the ladies of the United States Department of Agriculture for the noteworthy manner in which they have entertained the wives of the visiting delegates, thereby adding greatly to the comfort and pleasure of this group.

Eighth, we desire to record our great indebtedness to the various institutions and particularly by the foreign delegations for the preparation and installation of the excellent exhibits which have added so much to the educational value of the Congress.

Ninth, since several of the foreign governments represented at the Congress have indicated their intentions of presenting their exhibits to the United States Government, the Congress as a whole wishes to declare its appreciation for their expression of their generosity and good will.

Tenth, we desire also to record our indebtedness to the Press for their satisfactory publicity which has been given to the work and plans of the Congress, not only during the period of the meetings, but during the preceding months when important preliminary announcements were given to the public.

SIR JOHN RUSSELL (Chairman)
N. M. TULAIKAV,
W. H. STEVENSON,
M. F. MILLER,
Committee on Resolutions.

EXHIBITS OF THE FIRST INTERNATIONAL CONGRESS OF SOIL SCIENCE

E. Truog

Chairman of Exhibits Committee, University of Wisconsin, U. S. A.

In the spring of 1925 the President of the Congress suggested having exhibits of soil acidity apparatus and methods at the First International Congress of Soil Science and asked the writer to act as chairman of a committee to handle the matter. Accordingly, the following committee was appointed: S. D. Conner, Indiana Agricultural Experiment Station; H. J. Harper, Oklahoma Agricultural Experiment Station; F. W. Parker, Alabama Agricultural Experiment Station; R. M. Salter, Ohio Agricultural Experiment Station; C. H. Spurway, Michigan Agricultural Experiment Station; W. W. Weir, United States Bureau of Soils, F. L. Goll, United States Bureau of Plant Industry, and E. Truog, Wisconsin Agricultural Experiment Station.

The idea of having exhibits proved so fertile that by the time the Congress was held the exhibits had grown to include practically the whole field of soil science. The exhibits were naturally classified under the following heads: Soil Biology, Soil Classification and Mapping, Soil Chemistry, Soil Extension, Soil Fertility, Soil Literature, and Soil Physics. Four large rooms with a total floor space of approximately three thousand square feet, in the United States Chamber of Commerce Building, were assigned to the exhibits. This space, however, proved so inadequate that the exhibits overflowed into the corridors and even into the open court.

It was the splendid cooperation of the foreign delegates and visitors, and the soil workers and apparatus companies of this country that made the exhibits so extensive, varied, and valuable in many ways. The great interest taken in the exhibits was amply demonstrated by the large crowds that visited it from the first to the last day of the Congress. In fact, the exhibits gave one a new vision of the extensiveness of soil science and of the varied nature of the research work on soils which is being done in different countries.

On entering the building and going down the corridor to the left, one came first to the exhibit of American soil literature, which filled one of the smaller exhibit rooms. A corner of this display is shown in Fig. 1. Miss Claribel R. Barnett, Librarian, Agricultural Library, United States Department of Agriculture, was in charge of this exhibit and had on hand

FIGURE 1.—A corner of the exhibit of American Soil literature

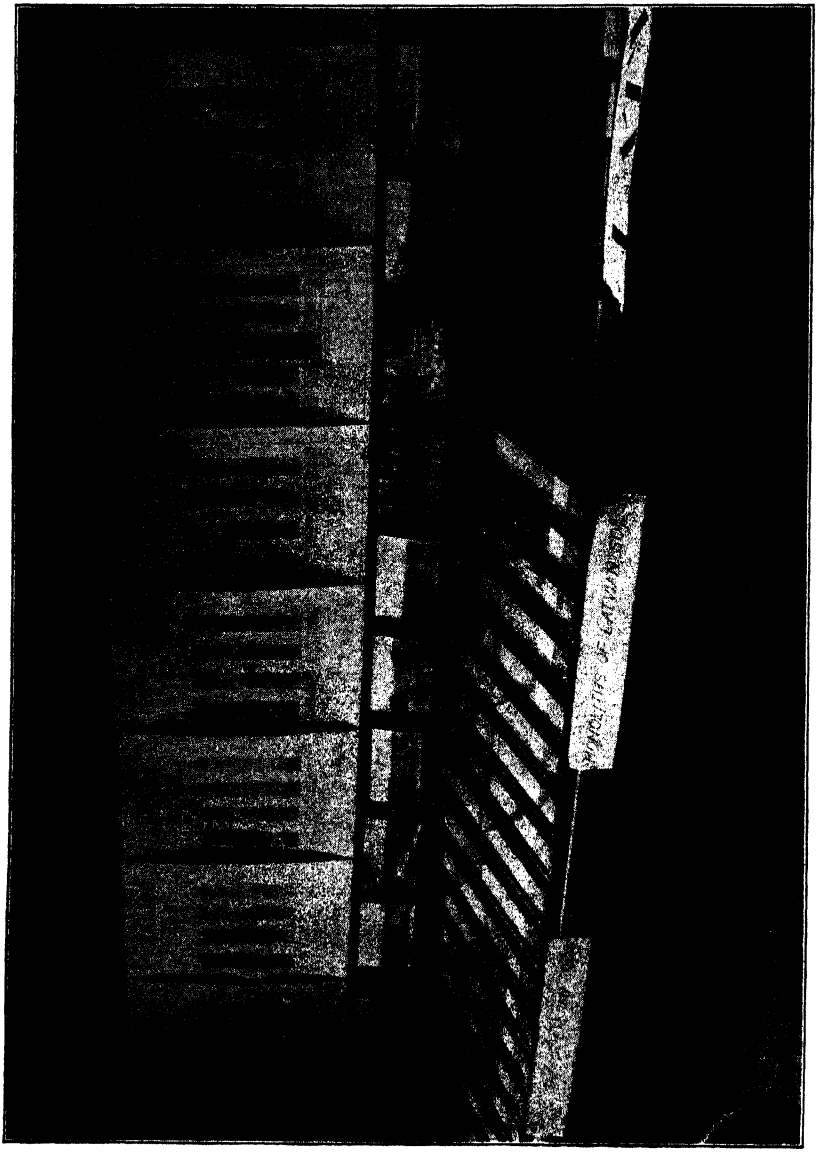

FIGURE 2.—Soil profiles and monoliths from Latvia

for free distribution *A Classified List of Soil Publications of the United States and Canada,* consisting of 549 pages, which she and her assistants had prepared especially for this Congress. Rare old books were on exhibit under glass, and books in common and current use were exhibited in racks. Photographs, printed matter, diagrams, and legends were displayed on panels hung on the walls. In referring to the exhibit, Miss Barnett speaks as follows: "There were three main purposes in the exhibit. An attempt was made, first, to picture the development, historically, of American soil science; second, to show the current literature on the subject with some of the more important aids in its use; and third, to serve as a reading and reference room during the Congress."

At the next door to the left, one came to the Executive Office of the Congress which of necessity had also to be used for exhibits. An extensive exhibit of elaborate and detailed soil maps was displayed on two walls of this room by H. Stremme, of Danzig. Along another side of this room was shown an excellent and carefully planned exhibit from Latvia, which was sent over by J. Wityn, who unfortunately could not attend the congress. This exhibit (fig. 2) included a large number of colored soil profiles on which were shown the influence of vegetation, drainage, and other factors in the development of soils. Eighteen larges oil monoliths were also displayed. Wityn specially prepared for this Congress an excellent and rather complete bulletin relating the soil investigations of Latvia. A supply of this bulletin was provided for free distribution.

Down the corridor, in the next room to the left, was located one of the outstanding exhibits; presented by the Russian delegates. Unfortunately their large and elaborate exhibit of soil monoliths was delayed in transit and did not arrive in time to be displayed. Their display of soil maps and soil literature was so large that it entirely filled a room twenty by forty feet. K. D. Glinka and Boris Polynov of Leningrad, Russia, were largely responsible for this exhibit which made one feel that the Russian soil scientists have a rightful claim to leadership in the field of soil classification and mapping. A large number of scientific papers dealing with soil chemistry and plant nutrition were shown. Many of these are not available in the libraries of our agricultural colleges. However, most of this literature has been given to the agricultural library of the United States Department of Agriculture, and most of the maps and charts have been given to the United States Department of Agriculture. Unfortunately, because of the nature of the material and the arrangement of the room, it was not practicable to take a picture of this display.

At the end of the corridor a large corner room, thirty by sixty feet, was completely filled with a variety of displays. Figures 3 and 4 give two views through the central part of the room, showing some of the exhibits of special apparatus used in soil investigation. This apparatus was exhibited by the Central Scientific Company, of Chicago, and Eimer and

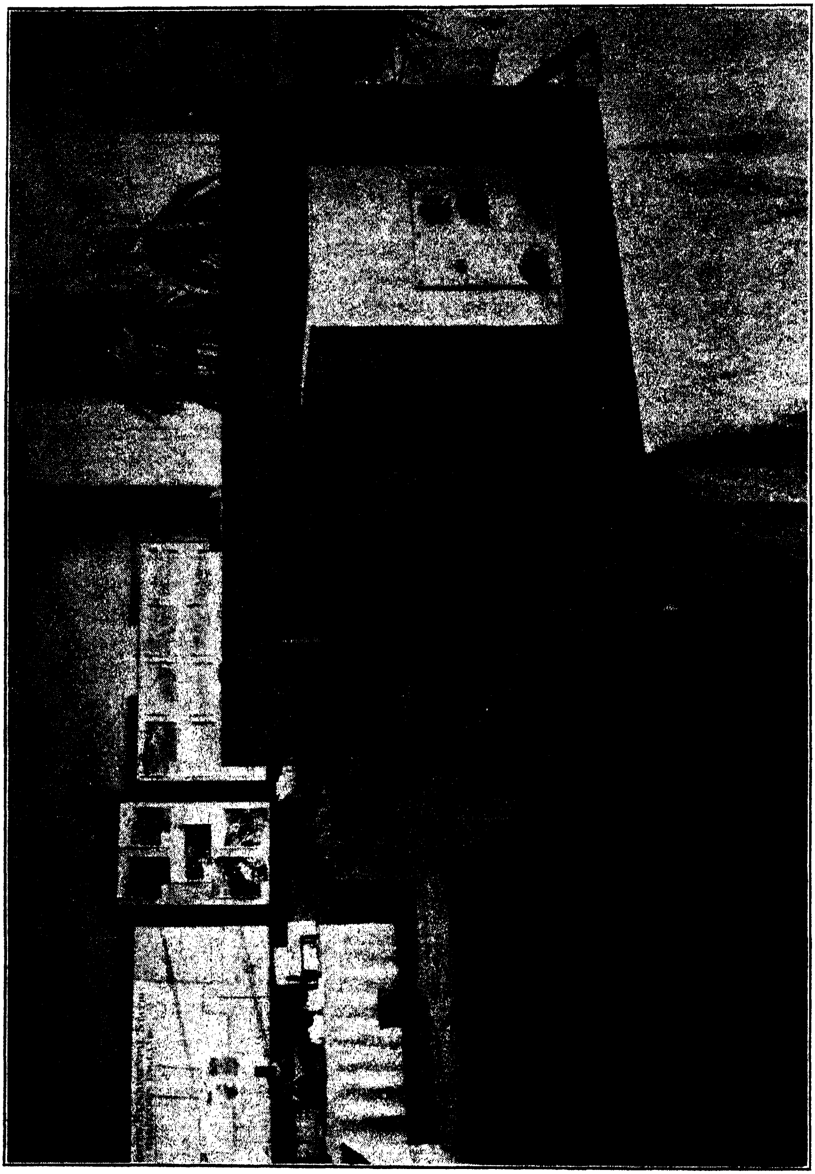

FIGURE 3.—View in the large exhibit room showing general apparatus for soil investigation

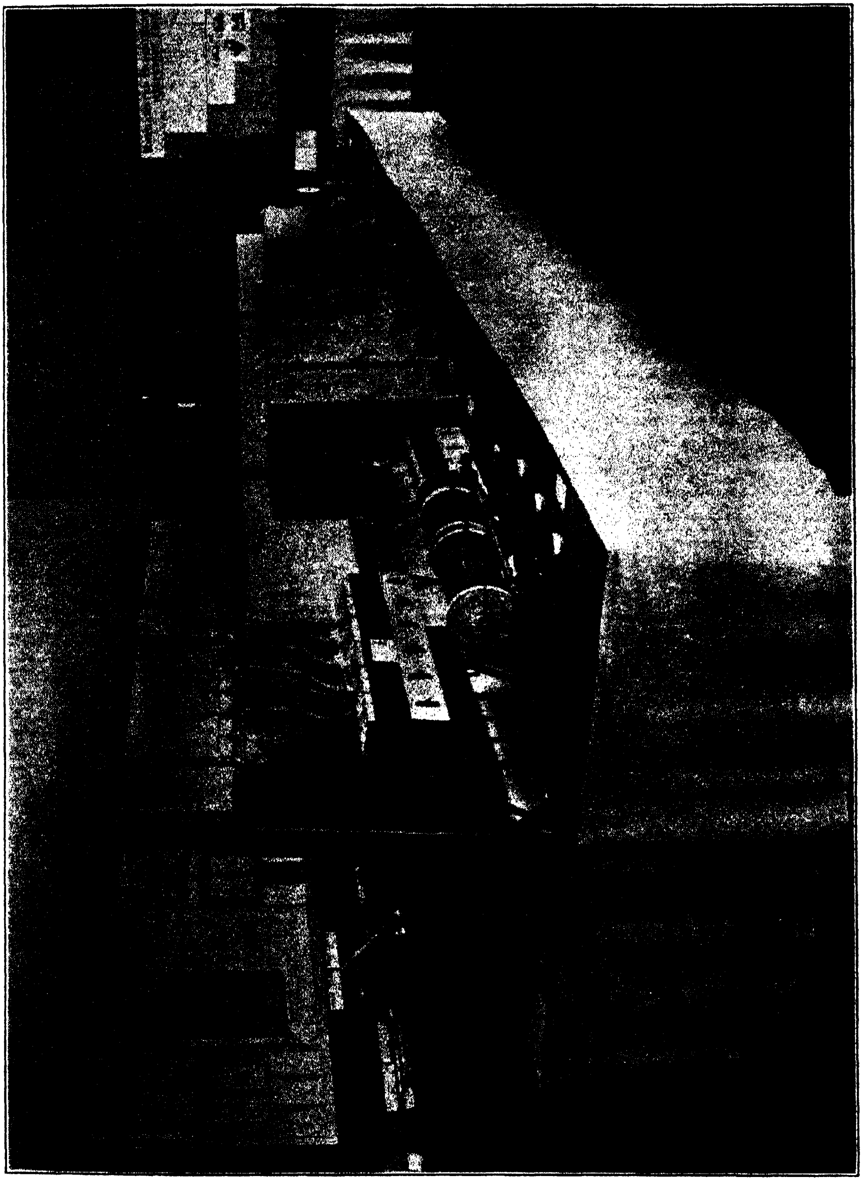

FIGURE 4.—View in the large exhibit room showing general apparatus for soil investigation

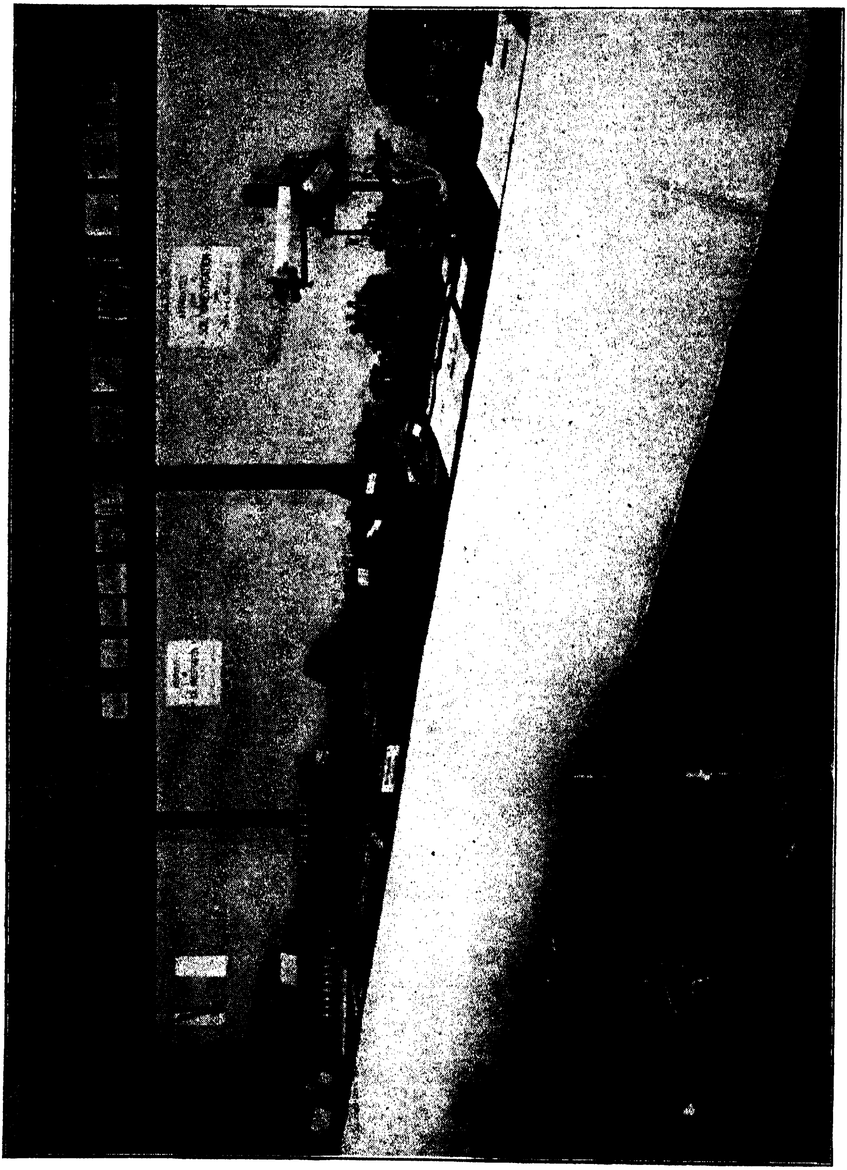

FIGURE 5.—A view in the large exhibit room showing apparatus for the colorimetric and electrometric determination of hydrogen ion concentration

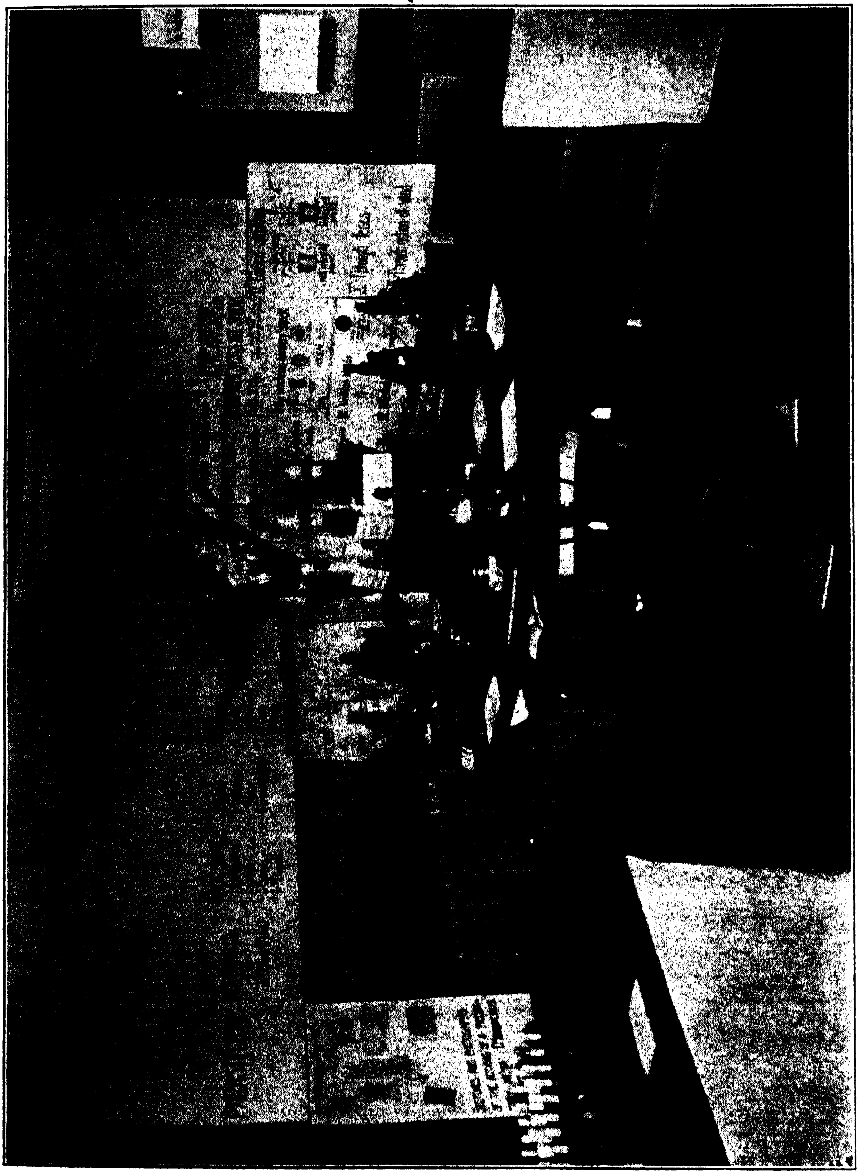

FIGURE 6.—A corner of the large exhibit room showing the revolving microscope table

Amend, of New York City. On the wall and table in the distance to the left of Fig. 3 is shown the display of the very ingenious dynamometer from the Rothamsted Experimental Station, of which B. A. Keen was in charge.

Figure 5 shows a corner of the large exhibit room. On the table in the center is an elaborate display of electrometric and colorimetric apparatus for the determination of hydrogen ion concentration, exhibited by Leeds and Northrup, of Philadelphia and LaMotte Chemical Products Company, of Baltimore. A few microscopes in the foreground are just a suggestion of the elaborate display of special microscopes, colorimeters, and other optical apparatus which were furnished by Bausch and Lomb Optical Company, E. Leitz, Incorporated, Spencer Lens Company, and Carl Zeiss, Incorporated.

On the wall to the right of Fig. 5 is shown a portion of the extensive exhibit illustrating strain variations in root-nodule bacteria. This exhibit was in charge of I. L. Baldwin and W. H. Wright, of the University of Wisconsin. Wright also demonstrated the use of his modified Chambers' Micro-Manipulator for isolating single cells of bacteria.

Figure 6 gives a close-up of this corner of the room and shows in detail the revolving, round, microscopic table, devised and exhibited by G. Steiner, of the United States Bureau of Plant Industry. With this table the student or investigator, from one seat, may have different microscopes loaded with various specimens brought before him by simply revolving the table. Nearby was an interesting exhibit of both root and aerial nodules, which was in charge of N. R. Smith, of the United States Bureau of Plant Industry. The direct plate method of showing the presence of Azotobacter in soils was illustrated by Mme. Ziemiecka, of Warsaw. Other exhibits of a biological nature were displayed by S. A. Waksman.

In Figure 7 is shown a view down one side of the large exhibit room. Water cultures on the table to the left illustrate the triangular method of fertilizer experiments. At the end of the table are shown some pot tests of the fertilizer value of manganese. Opposite is an exhibit of specimens of organic chemical compounds isolated from soils. This material was exhibited by Oswald Schreiner, of the United States Bureau of Plant Industry. Colored pictures on the wall and a model on the table in the distance illustrate soil erosion problems and methods of control.

Figure 8 shows an exhibit along one wall of the large exhibit room. To the left is illustrated the cornstalk method of G. N. Hoffer, of Indiana, for determining fertilizer needs of soils. In the center on both the wall and table is shown a display relating to peat investigations. This was in charge of A. P. Dachnowski-Stokes, of the United States Bureau of Plant Industry. On the wall at the extreme right is shown a portion of the display relating to extension methods in agriculture. This was in

FIGURE 7.—A view of the large exhibit room illustrating on the table to the left the triangular method of fertilizer experiments, and on the table and wall in the distance, soil erosion problems and control

FIGURE 8.—A view of exhibits illustrating the corn stalk method of testing for fertilizer needs, peat investigations and extension methods

charge of O. S. Fischer, Extension Service, United States Department of Agriculture.

Figure 9 gives a view of the elaborate apparatus for determining the oxygen-supplying power of the soil, exhibited by L. Hutchins, of the United States Bureau of Plant Industry.

It is impossible to show by pictures all of the exhibits in the large exhibit room. A few more should, however, be mentioned: viz., a display of Pyrex glass by Corning Glass Works; a soil sampler and a modified Wiegner tube by R. Bradfield, of Missouri; an exhibit of alumina and iron oxide colloids of the University of Palestine, Jerusalem; an auto-irrigator for pot cultures by E. P. Deatrick, of West Virginia; an apparatus for determining soil color by J. G. Hutton, of South Dakota; special physical apparatus by C. H. Spurway and G. J. Bouyoucos, of Michigan; a miniature plant for fixation of atmospheric nitrogen by the Fixed-Nitrogen Laboratory of the United States Bureau of Soils; various concentrated fertilizer materials by the United States Bureau of Soils; activated sludge fertilizer and its manufacture by O. J. Noer, Sewerage Commission, Milwaukee, Wisconsin.

In the corridor leading to the open court was displayed the set of soil profiles shown in Fig. 10. These came from Hungary and were in charge of Peter Treitz, of Budapest. Their particular interest lay in the fact that the soil was conserved in its natural state by means of a new method devised by Sigmund Pinkert, of the Royal Hungarian Geological Survey. This method makes possible the collection and preservation of natural soil-type specimens in very thin sections, thus enabling the specimens to be transported and handled very easily and without danger of damage. The special process used fixes the soil in its natural condition so that the columns may be set upright without any danger of the soil falling out, although the face of the columns are not protected with glass. Details of this method can be obtained from either Treitz or Pinkert.

The United States Bureau of Soils displayed numerous large soil monoliths in the open court and many soil maps in an adjacent corridor. In the open court there also was displayed by A. G. McCall, of the University of Maryland, a simple type of revolving greenhouse table for plant culture work.

The Bureau of Soils laboratory exhibit contained a soil penetrometer for field use, a high speed centrifuge for the determination of the molecular moisture holding capacity of soils, a soil briquette apparatus, a filter for concentrating suspended soil colloids, and an electrodialysis cell.

Unfortunately, it is not possible to mention all the exhibits and all those who cooperated so splendidly in helping to make the exhibits a success. Special mention should be made of the part played by W. W. Weir, of the United States Bureau of Soils, and F. L. Goll, physiologist of the Bureau of Plant Industry. These men were largely responsible

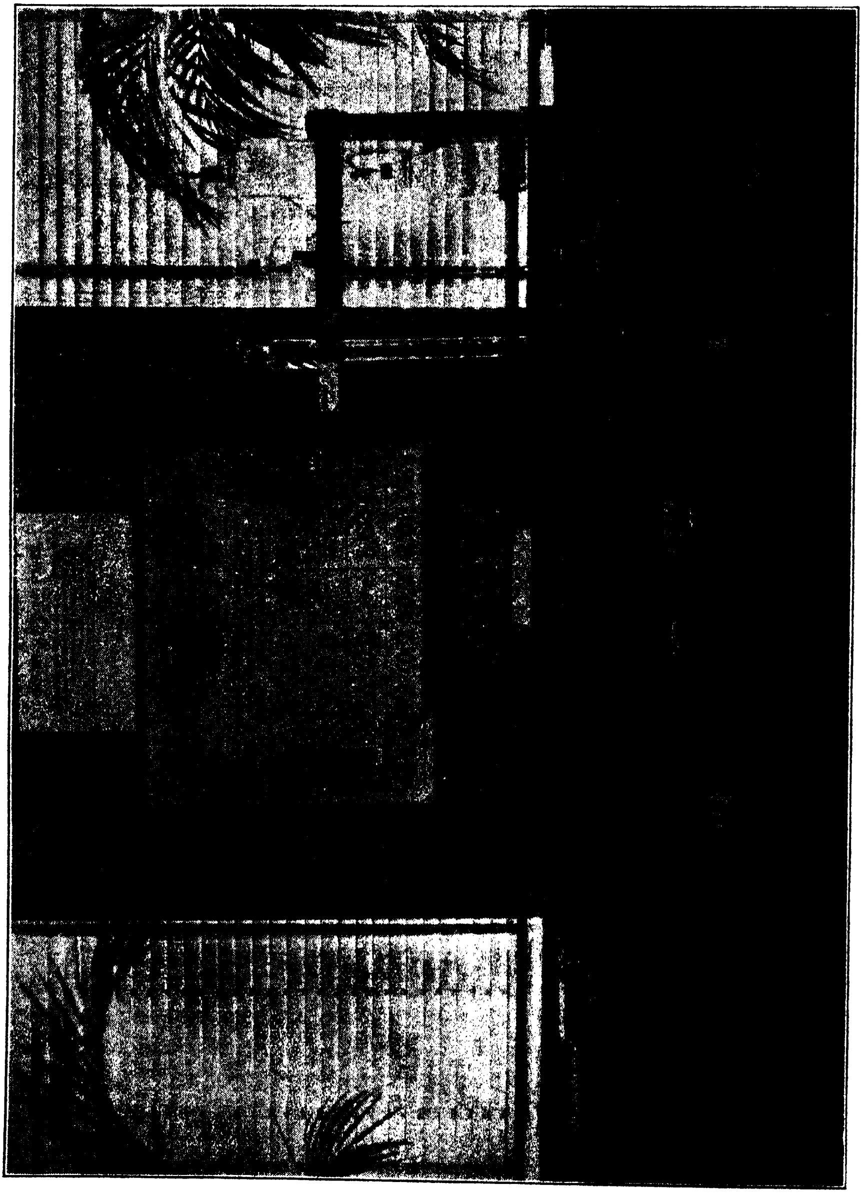

FIGURE 9.—Apparatus for determining the oxygen-supplying power of soils

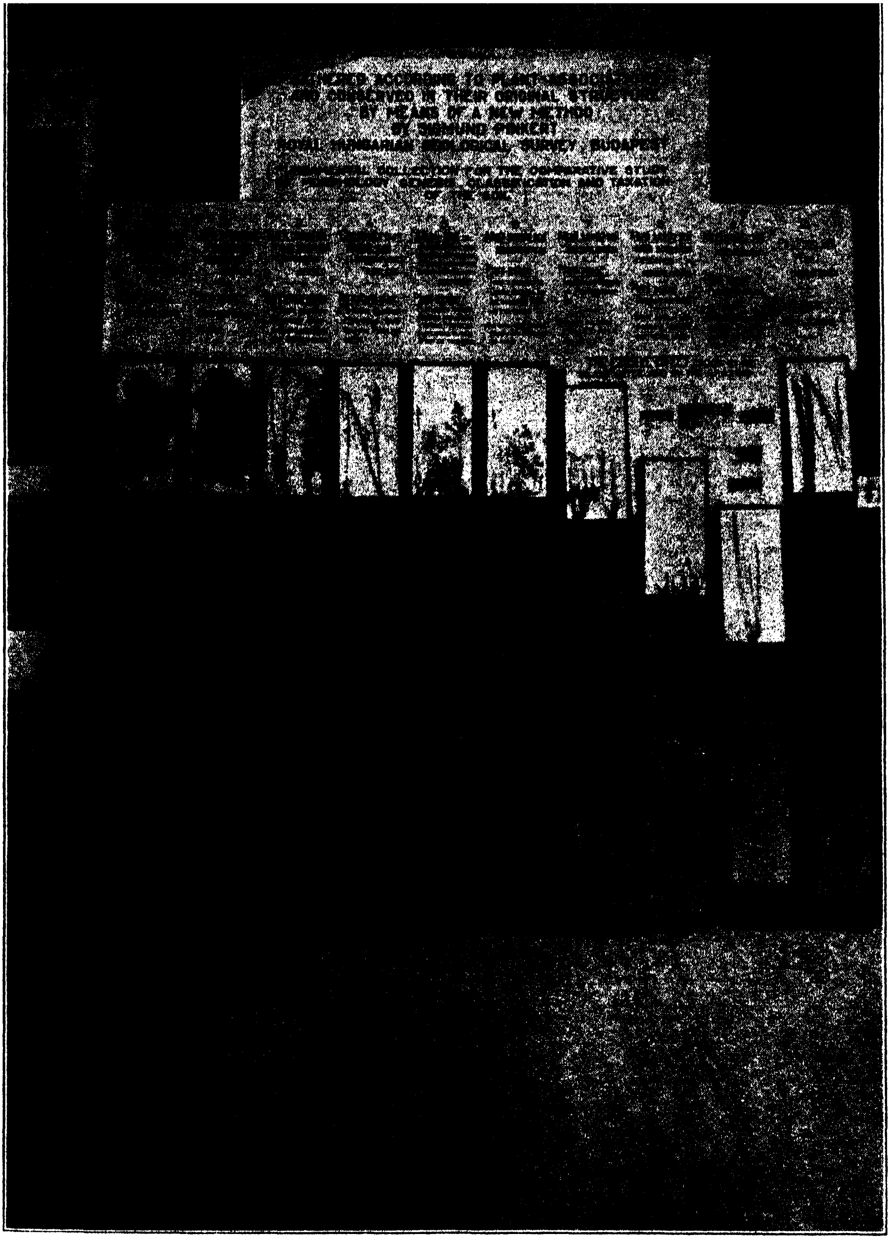

FIGURE 10.—Natural soil profiles with vegetation from Hungary, collected and preserved by means of a new method

for arranging and placing the material. F. L. Goll also shouldered the great responsibility of dismantling and returning much of the material. Many thanks are due Mr. Shipman, superintendent of the United States Chamber of Commerce Building, who gave the exhibits committee his most hearty and immediate personal attention in handling the numerous perplexing problems which arose.

REPORTS OF THE SECRETARIES OF THE COMMISSIONS

WASHINGTON SESSIONS

SPECIAL SESSIONS

Reports of the Secretaries of Commissions

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This commission met June 18, 10 A.M., and June 20 at the same hour in a joint session with Commission II and IV and a detailed report of this session is to be found in Dr. Comber's report of Commission II.

COMMISSION II

THE STUDY OF SOIL CHEMISTRY

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Dr. A. A. J. de'Sigmond addressed the joint session of Commissions II and IV as follows:

JOINT SESSION COMMISSIONS II AND IV

Ladies and Gentlemen: As chairman of the Second Commission for Soil Chemistry it gives me pleasure to welcome cordially all the members who have attended our meeting.

Before we begin our work it is my sorrowful duty to express our sorrow and sympathy for the loss of two prominent collaborators of our Commission, Dr. H. Christensen (Denmark) and Prof. Dr. A. Vesterberg (Sweden), who have died since the last Commission Meeting at Groningen.

As an expression of our deep sorrow and regret I request that we rise for a moment and stand in silent and humble devotion to our Lord.

According to the order of the day we will have a joint meeting of the Second and Fourth Commission on Plant Nutrient questions of both Commissions.

A period of five minutes is allowed each one presenting a report and a two minute period is allowed for discussion.

After these opening remarks reports of previous meetings of this Commission were read:

PRELIMINARY MEETINGS

I. Soil Adsorption.—Dr. D. J. Hissink, Groningen, Special Referee, together with Associate Referees, Dr. N. M. Comber, Leeds and Dr. O. Lemmermann, Berlin, reported the proceedings of the Groningen meeting concerning their work on soil-adsorption.

SOIL-ADSORPTION

Report of the Proceedings of the Second Commission, Groningen, 1926.
Dr. D. J. Hissink, Referee

At the final meeting of the Second Commission, held in May 1924, during the conference at Rome, the duty of reporting on the questions of soil

adsorption was entrusted to me. I have already partly fulfilled this duty, during the Groningen Meeting in April 1926, and refer, so far as this is concerned, to Volumes A and B.

I have already treated the questions of soil adsorption theoretically in Volume B (1) and also in my Faraday lecture (2) and would therefore confine myself here to a few remarks on this point.

In his paper on "Replaceable Bases in Soils," page 34, Kelley makes the following remark:

"Hissink also found that a lesser amount of leaching with salt solutions is required to remove the replaceable monovalent bases than the divalent bases. Our experience is in agreement with theirs. It is difficult to harmonize these facts with the absorption hypothesis of Hissink. If every atom of a given base is located on the exposed surface of particles, as he assumes, one should be as readily displaced as another."

Kelley is inclined to think that the explanation is that more than one chemical compound is involved. I hardly think this can be the case. I made my tests with artificially prepared sodium and calcium soils, in which all the bases were replaced by sodium and calcium, respectively, so that I worked both times with soils of the same chemical constitution, except for the fact that one soil contained exchangeable sodium and the other exchangeable calcium. May there not be some relation between the displaceability of the univalent and bivalent bases on the one hand, and the solubility of their silicates and humates on the other hand? I shall be glad to hear the views of my colleagues and especially of Kelley and Brown on this point.

It was only my intention to study in general the proposed methods as originally laid down; it was not my intention to ascertain whether any modifications were advisable.

The proposed methods are to be found in Volume B (p. 175). It will be noted that the number of these has been increased, and that I have included, among others, Hutchinson's method. I tried out these methods on a series of Dutch soils of widely different types. I chose for this purpose eight different experimental fields of six different types, and from each field I took one sample from a limed plot and one from an unlimed one.

Description of the Soil Samples

B 1690 and 1691. Two samples of surface soil (0–23 cm.) from the Experimental Garden at Sappemeer (Province of Groningen); mixture of sand and very well humified high peat; about 23 per cent humus. B 1690 was taken from Plots A 1 and A 3, which received only stable manure; B 1691, from Plots C 2 and C 4, which received only artificial fertilizers (potash, superphosphate and sulfate of ammonia).

B 1718 and 1724. Two samples of surface soil (0–15 cm.) from the

Experimental Field at Harkstede (Province of Groningen); well humified low peat; very rich in humus (about 50 per cent), with some clay. B 1718 was taken from Plot B 10, which received 6000 kg. CaO per ha. in the form of limecake; B 1724 from Plot C 6, which received no lime. Both plots received potash and phosphate, but no nitrogen.

B 2145 and 2146. Two samples of surface soil (0–22 cm.) from the Experimental Field at Eelderwolde (Province of Groningen); well humified low peat; very rich in humus (about 45 to 50 per cent), with a little clay. B 2145 was taken from half of Plot 2, which received 2300 kg. CaO per ha. in the form of limecake; B 2146 from the other half, which was not limed. The whole plot received stable manure, but no artificial fertilizers.

B 2329 and 2330. Two samples of surface soil from an Experimental Field at Eersel (Province of North Brabant); humus sandy soils, poor in humus (about 5 to 6 per cent humus). B 2329 received liquid manure and Thomas slag; B 2330 the very small amount of about 480 kg. CaO per ha. and further stable manure, superphosphate and potash.

B 1697 and 1698. Two samples of surface soil from an Experimental Field at Schildwolde (Province of Groningen); heavy clay soil, relatively rich in humus (about 9 to 12 per cent). B 1698 was taken from the limed half of the field, which received 20,000 kg. limecake per ha. (about 4000 kg. CaO); B 1697 from the unlimed half. Both parts of the field were manured with artificial fertilizers.

B 2335 and 2337. Heavy loamy soils, practically without humus, from two spots on moorland at Roden (Province of Drenthe). B 2335 (depth 30–50 cm.) is covered with low peat; B 2337 (depth 75–100 cm.) with sandy loam. The soils were never manured.

B 1937 and 1939. Two samples of surface soil (0–23 cm.) from an Experimental Field in Overlangbroek (Province of Utrecht); grassland; very heavy river clay, relatively rich in humus (8 to 9 per cent). B 1937 was taken from the limed plot, which received in 1915, 1920 and 1923 each time 10,000 kg. slaked lime per ha.; B 1939 from the unlimed plot.

B 1944 and 1946. Two samples of surface soil (0–23 cm.) from an Experimental Field at Amsweer (Province of Groningen); arable land; heavy marine clay with little humus (about 2 per cent). B 1944 received 12,000 kg. CaO in the form of lime cake; B 1946 was not limed.

With the exception of 2329, 2330, 2335 and 2337 all the soil samples were taken from fields already described in Volume A (p. 175; p. 198).

B 1690 and 1691 were, however, taken again in October 1924; and B 1718 and 1724 were taken again in October 1926. B 2145 corresponds to B 1858 and B 2146 to B 1859, but they were taken in May 1926.

Composition of the Soil Samples

Table 1 shows the composition of these 16 soils. The pH was determined by the Biilmann electrode in water suspensions (10 g. soil with 25

TABLE 1—Composition of soil samples

	Soil sample No. B	Percent of H_2O in air-dried soil	pH	Percentages in dried soil (105° C.)										Degree of saturation (V)	Per 100 parts exchangeable bases are present (relative proportion of bases)			
				$CaCO_3$	Organic matter	Clay (I+II)	Sand (III+IV)	Exchangeable bases				Total bases in milligr. equivalents per 100 g. soil (S)	Potential adsorption (calculated)					
								CaO	MgO	K_2O	Na_2O				Ca	Mg	K	Na
Sappemeer	1690	16.9	5.03		23.1	8.4	68.5	0.653	0.062	0.043	0.064	29.4	0.594	21.5	79	11	3	7
	1691	13.6	4.22		22.9	7.7	69.4	0.359	0.077	0.055	0.104	21.2	0.871	14.9	60	18	6	16
Harkstede	1718	30.9	5.90	0.76	48.2	33.1	18.7	1.867	0.105	0.048	0.103	76.2	0.907	28.0	88	7	1	4
	1724	31.4	4.58	0.60	48.0	31.9	20.1	1.079	0.104	0.033	0.085	47.1	1.672	15.9	82	11	1	6
Eelderwolde	2145	31.6	5.26	0.53	45.4	17.2	37.4	1.512	0.073	0.072	0.060	61.1	0.947	25.7	88	6	3	3
	2146	38.1	5.10	0.51	49.2	20.2	30.6	1.430	0.081	0.087	0.099	60.3	1.252	23.4	85	7	3	5
Eersel	2329	1.8	5.03		5.0	10.1	84.9	0.093	0.009		0.007	4.0	0.268	11.9	82	13		5
	2330	1.9	4.13		5.8	9.3	84.9	0.055	0.020	0.009	0.017	3.7	0.337	9.7	54	27	5	14
Schildwolde	1698	8.2	6.83		9.7	59.2	31.1	0.791	0.017	0.012	0.027	30.4	0.345	34.9	93	3	1	3
	1697	8.8	4.83		12.6	63.7	23.7	0.366	0.023	0.018	0.047	16.1	0.965	16.5	81	7	3	9
Roden	2335	7.3	6.28		1.5	86.2	12.3	0.809	0.129	0.019	0.049	37.4	0.224	50.9	77	18	1	4
	2337	7.4	5.07		1.7	78.2	20.1	0.507	0.151	0.048	0.074	29.1	0.438	41.9	62	26	4	8
Overlangbroek	1937	5.4	7.35	1.49	8.5	70.0	20.0	1.139	0.117	0.034	0.022	48.0	0.056	48.3	85	13	1	1
	1939	5.8	6.19	0.19	8.8	73.2	17.8	0.849	0.128	0.024	0.039	38.5	0.396	40.6	79	17	1	3
Amsweer	1944	4.0	7.83	1.29	2.2	54.3	42.2	0.665	0.081	0.023	0.035	29.5	0.042	53.2	80	14	2	3
	1946	4.6	7.56	0.57	1.8	56.8	40.8	0.608	0.103	0.029	0.034	28.6	0.107	53.1	76	18	2	4

cc. of water). The exchangeable CaO was determined according to Hissink (with sodium chloride); the exchangeable MgO, K_2O and Na_2O by leaching 25 g. of air-dried soil with one liter of N NH_4Cl solution (Kelley's method). For the value V (degree of saturation according to Hissink) see also Table 2 ($V = 100\ S:\ T$).

According to Table 1 the soil samples 1718, 1724, 2145 and 2146 all contain small amounts of calcium carbonate. It is strange that such acid soil as B 1724 (pH of 4.58), which never received any lime, should contain calcium carbonate. It is not impossible that when determining calcium carbonate (boiling of the soil with hydrochloric acid) in soils such as these four, which are very rich in humus, a small quantity of carbon dioxide is formed by the oxidation of carbon (see also Volume A, p. 197, remark 2).

For the potential adsorption see Volume A, p. 183. It is the amount of calcium oxide that can be absorbed by the clay-humus-substance under natural conditions. This figure depends on the one hand on the clay and humus contents of the soil, and on the other hand on the degree of saturation (V) of the clay-humus-substance and on the maximum V that this substance can reach under natural conditions. I have calculated this amount assuming that the highest K values under Dutch climatic conditions are:

$$\text{K (clay)} = 1.1 \text{ and K (humus)} = 5.0^{1}.$$

The calculation is as follows: With K values respectively 5.0 and 1.1 100 g. dried soil B 1690 (with 23.1 per cent humus and 8.4 per cent clay) contains $(23.1 \times 5 + 8.4 \times 1.1) : 100 = 1.247$ g. CaO. Since B 1690 contained 0.653 per cent CaO, the clay-humus-substance of 100 g. dried soil (105° C.) can take up under the prevailing climatic conditions $1.247 - 0.653 = 0.594$ g. CaO. This figure is introduced as the *potential adsorption.*

Some Explanatory Remarks on the Figures in Tables 2 and 3

All values in Table 2 are expressed in milligram equivalents (me.) on 100 g. dried soil (105° C.) and will here be calculated for the first sample B 1690.

The S-values of Kelley (total bases and NH_4-adsorbed), Hissink, and Bobko-Askinasi (28.9 – 29.3 – 22.3 – 32.8), require no further explanation.

The titration according to Gedroiz gave, for B 1690, in 3 liters: $1.86 + 1.31 + 0.78 = 3.95$, in round figures, 4.0 me. Assuming that in the place of the replaced H an equivalent amount of Ba is adsorbed by the clay-humus-substance, the soil will contain after the leaching with barium chloride: 29.4 (S-Hissink) $+ 4.0 = 33.4$ me. bases in the adsorbed condition.

[1] As can be seen from these figures, it is especially the humus which adsorbes the CaO. In well saturated Dutch soils, in a natural condition, 100 g. of humus contain *about* 5 g. CaO and 100 g. clay (I+II) *about* 1.1 g. CaO. These figures are of course to be regarded as a first approximation.

TABLE 2—Milligram equivalents

Soil sample No. B	pH	S-Kelley		S-Hissink (see Table A)	Bobko and Askinasi	Gedroiz		Hutchison and MacLennan		Kappen		Gehring and Wehrmann				Hissink		Titration with CaO till pH =						Potential adsorption (see Table 1)	
		Total bases	NH_4 adsorbed[a]									25, resp. 10 g. of soil		10, resp. 5 g. of soil		*T—S*	*T*	6.0		6.5		7.0			
1690	5.03	28.9	22.3	29.4	32.8	4.0	33.4	9.5	38.9	9.9	39.3	11.0	40.4	24.6	54.0	107.5	136.9	5.0	34.4	10.8	40.2	18.9	48.3	21.2	50.6
1691	4.22	21.4	18.0	21.2	27.3	6.2	27.4	16.7	37.9	17.1	38.3	17.8	39.0	31.6	52.8	120.8	142.0	13.8	35.0	22.5	43.7	32.1	53.3	31.1	52.3
1718	5.90	71.0	61.8	76.2	77.5	2.2	78.4	8.9	85.1	9.5	85.7	17.6	93.8	55.9	132.1	196.2	272.4			5.6	81.8	20.5	96.7	32.4	108.6
1724	4.58	43.8	41.4	47.1	55.4	11.2	58.3	27.5	74.6	26.9	74.0	37.5	84.6	68.7	115.8	248.9	296.0	21.3	68.4	38.6	85.7	60.0	107.1	59.7	106.8
2145	5.26	62.0	45.3	61.1	66.0	2.3	63.4	11.9	73.0	12.6	73.7	23.0	84.1	64.5	125.6	176.7	237.8	5.5	66.6	14.3	75.4	26.8	87.9	33.8	94.9
2146	5.10	57.9	45.3	60.3	65.1	4.2	64.5	18.4	78.7	19.2	79.5	33.2	93.5	81.1	141.4	197.5	257.8	11.2	71.5	21.6	81.9	35.7	96.0	44.7	105.0
2329	5.03	4.4	3.8	4.0	6.5	1.9	5.9	4.9	8.9	4.5	8.5	13.3	17.3	22.1	26.1	29.7	33.7	2.6	6.6	5.1	9.1	8.4	12.4	9.6	13.6
2330	4.13	3.8	3.8	3.7	7.7	4.1	7.8	6.7	10.4	6.1	9.8	13.8	17.5	26.6	30.3	34.4	38.1	5.8	9.5	8.4	12.1	11.5	15.2	12.0	15.7
1698	6.83	32.2	25.1	30.4	31.0	−1.0		0.1	30.5	1.8	32.2	9.6	40.0	28.1	58.5	56.8	87.2					0.8	31.2	12.3	42.7
1697	4.83	18.4	18.1	16.1	24.5	3.5	19.6	10.6	26.7	10.0	26.1	17.3	33.4	32.3	48.4	81.2	97.3	7.2	23.3	14.2	30.3	21.4	37.5	34.5	50.6
2335	6.28	36.9	33.5	37.4	37.0	0.7	38.1	1.5	38.9	1.4	38.8	13.4	50.8			36.1	73.5					1.4	38.8	7.6	45.0
2337	5.07	28.3	27.7	29.1	28.6	0.7	29.8	6.8	35.9	4.8	33.9	18.0	47.1			40.3	69.4	3.4	32.5	5.3	34.4	7.0	36.1	15.6	44.7
1937	7.35	66.7	34.5	48.0	45.9	−7.3		−1.4		1.3	49.3	4.2	52.2	14.0	62.0	51.3	99.3							2.0	50.0
1939	6.19	40.4	32.0	38.5	39.0	0.2	38.7	2.8	41.3	3.5	42.0	12.5	51.0	27.9	66.4	56.4	94.9			0.9	39.4	5.9	44.4	14.1	52.6
1944	7.83	40.9	18.1	29.5	21.8	−7.9		−6.5		0.6	30.1	4.0	33.5			25.9	55.4							1.5	31.0
1946	7.56	31.9	19.4	28.6	22.0	−2.6		−0.8		0.7	29.3	6.2	34.8			25.3	53.9							3.8	32.4

[a] Corrected.

With Hutchinson's method 10 g. of air-dried soil B 1690 were shaken with 200 cc. of calcium bicarbonate, 100 cc. of which titrated 20.6 cc. 0.1 *N* HCl, whilst 100 cc. of the soil filtrate titrated 16.6, so that per 5 g. of air-dried soil $(20.6-16.6)\times 2.8$ mg. CaO was adsorbed or 0.224 g. CaO per 100 g. air-dried soil. Now the air-dried soil contains 16.9 per cent water (see Table 2). If this is taken into account, then 0.272 g. CaO is adsorbed per 100 g. dried soil. The duplicate determination gave 0.258, the average being 0.265 g. CaO = 9.5 me. CaO. The original soil contained 29.4 me. (*S*-Hissink); after the treatment with calcium bicarbonate the soil contained adsorbed: $29.4+9.5=38.9$ me. bases.

With Kappen's method 100 g. of air-dried soil B 1690 were shaken with 250 cc. *N* Ca $(C_2H_3O_2)_2$ solution; 125 cc. of the filtrate titrated 37.5 cc. 0.1 *N* NaOH solution. Per 100 g. air-dried soil was thus adsorbed: $2\times 37.5\times 2.8=210$ mg. $\times 0.210$ g. CaO. The duplicate determination titrated 39.5 cc. 0.1 *N* NaOH, that is 0.221 per cent CaO adsorbed, the average being 38.5 cc. or 0.2156 per cent CaO adsorbed. Allowing for the water content of the air-dried soil (16.9 per cent) then 0.277 g. CaO = 9.9 me. was adsorbed per 100 g. dried soil. The original soil contained 29.4 me. (*S*-Hissink); after the treatment with calcium acetate the soil contained adsorbed: $29.4+9.9=39.3$ me. bases.

As is known, Kappen employs the factor 1½. Taking this factor into account, and assuming also that 1½ times the amount of CaO is actually adsorbed by the soil (i.e. $1.5\times 0.277=0.4155$ per cent), the soil contains in this case: $29.4+(1\frac{1}{2}\times 9.9)=44.2$ me. adsorbed. This figure is not included in Table 2.

According to Kappen (Volume B, p. 179) a sufficiently accurate measure of the amount of lime needed to bring the soil to neutrality is provided by multiplying the alkali titer 38.5 by the factor 4.5. This gives the number of double centriers of pure $CaCO_3$ needed per ha. (3,000,000 kg.) i.e. in this case: $38.5\times 4.5=173.2$ double centriers = 17,320 kg. $CaCO_3$. This figure can also, of course, be obtained in this way: $10{,}000\times(0.2156\times 1\frac{1}{2}\times 3):56=173.2$. When, however, the moisture content is taken into account, we obtain: $10{,}000\times(0.277\times 1\frac{1}{2}\times 3):56=222.6$.

This shows that the water content of soils like these, which contain a great deal of water in an air-dried condition, has a great influence on the results, and must therefore be taken into account.

Twenty-five grams of soil B 1690, treated according to Gehring, gave on leaching with sodium chloride 0.960 per cent CaO (in dried soil); the content of exchangeable CaO in the original soil being 0.653 per cent CaO, $0.960-0.653=0.307$ per cent CaO = 11.0 me. was adsorbed per 100 g. dried soil. The original soil contained 29.4 me. (*S*-Hissink) adsorbed bases; after the treatment according to Gehring the soil contained adsorbed $29.4+11.0=40.4$ me. bases. If 10 g. of soil is treated, the result is: $29.4+24.6=54.0$.

$T-S$ according to Hissink is 107.5, which gives $T = 107.5+29.4 = 136.9$. The result of the titration with CaO is that 5 me. CaO per 100 g. dried soil B 1690 are required to reach a pH of 6. With a pH of 6 this soil therefore contains $29.4+5.0 = 34.4$ me. bases adsorbed. With a pH of 6.5 the figures are: $29.4+10.8 = 40.2$; with a pH of 7: $29.4+18.9 = 48.3$.

TABLE 3.—Comparison of hydrogen ion concentration as determined by Kelley's and Kappen's methods

Soil sample No. B	pH of the water suspension (see Table 1)	Potassium chloride solution				Calcium acetate solution			
		pH of the KCl soil-suspension	pH of the filtrate of this suspension	pH of the water soil suspension after the treatment with KCl	mg. $Al_2O_3+Fe_2O_3$ per 125 cc. of the filtrate, i.e. per 50 g. air-dried soil	pH of the calcium-acetate-soil-suspension	pH of the filtrate of this suspension	pH of the water soil suspension after the treatment with calcium acetate	mg. $Al_2O_3+Fe_2O_3$ per 125 cc. of the filtrate, i.e. per 50 g. air-dried soil
1690	5.03	4.55	4.96	6.05	1.5	5.78	5.78	6.44	3.0
1691	4.22	3.55	3.65	5.53	9.6	5.51	5.51	6.34	3.8
1718	5.90	5.45	6.25	6.76		5.85	5.88	7.05	
1724	4.58	3.89	4.05	5.34	7.3	5.41	5.41	6.40	6.4
2145	5.26	4.94	5.64	6.60		5.80	5.83	6.57	
2146	5.10	4.58	5.64	6.14	1.2	5.67	5.67	6.57	1.2
2329	5.03	4.34	4.90	6.34	2.5	6.04	6.04	6.57	2.0
2330	4.13	3.85	4.31	5.70	7.3	5.91	5.91	6.60	1.0
1698	6.83	6.03	6.63	7.50		6.49	6.52	7.05	
1697	4.83	3.88	4.22	5.70	14.8	5.72	5.73	6.44	2.5
2335	6.28	5.26	6.48	6.32		6.53	6.66	6.91	
2337	5.07	4.00	4.33	6.03	33.3	6.03	6.11	6.22	2.7
1937	7.35	6.83	7.11	8.16		6.59	6.73	7.85	
1939	6.19	5.19	5.25	7.05		6.19	6.25	6.96	
1944	7.83	7.24	7.18	8.72		6.99	7.15	8.46	
1946	7.56	7.54	6.73	8.30		6.85	7.08	7.56	

According to Table 1 the potential adsorption of B 1690 is 0.594 g. CaO, that is 21.2 me. CaO. When the soil has fixed this amount, it contains $29.4+21.2 = 50.6$ me. bases in the adsorbed condition, i.e. adsorbed in the clay-humus-substance.

Table 3 shows in the first place the pH of the water soil suspension (see Table 1). It further shows the pH of the KCl soil suspension (100 g. air-dried soil per 250 cc. N KCl solution); the pH of the filtrate of this suspension and also the pH of the soil on the filter, after it had been washed with

and shaken in water. Finally the number of mg. $Al_2O_3+F_2O_3$ per 125 cc. of the filtrate (i.e. per 50 g. air-dried soil) is also given. The same data as for potassium chloride are also given for the calcium acetate solution (Kappen's method). I also tried to get the same data for calcium bicarbonate (Hutchinson's method) but the agreement between the duplicate determinations was not very satisfactory (Tables 1 and 3).

Discussion of the Methods

S-value.—In soils containing no calcium carbonate the determination of the *S*-value presents relatively little difficulty, the only question in this case being the amount of soil to be leached out. Generally speaking, less substance should be taken of soils rich in exchangeable bases, that is, especially, soils which are slightly acid to alkaline and rich in humus. In the case of these soils also, of course, two liters may be leached out at each leaching instead of one.

That the differences in the *S*-value of these soils are but slight, whatever method is used, may be seen by comparing Kelley's figures (total bases) with mine: for instance B 1690: 28.9 and 29.4. If, however, the soil contains calcium carbonate, some difficulties are encountered, since part of the calcium carbonate is brought into solution by the neutral salts used for leaching. In my opinion a sodium chloride solution can be used in this case as sodium chloride dissolves practically the same amount of calcium carbonate in the first liter as in the second. The soil might also, according to Gedroiz, be leached with sodium chloride and the amount of calcium carbonate that has gone into solution be determined by testing the leached soil. It will be advisable to compare these two methods, but I have not yet had time to do so.

At any rate leaching with ammonium chloride gives, in the case of soils containing calcium carbonate, too high results, as can be seen by comparing Kelley's figures (total bases) with mine; for instance B 1944 (with 1.29 per cent $CaCO_3$); *S*-Kelley 40.9 and *S*-Hissink, 29.5; etc.

Kelley (total bases and NH_4-adsorbed).—The blank was determined by boiling the original soil with sodium hydroxide. Table 4 shows the results of the blank determinations in milligram equivalents per 100 g. soil, together with the *S*-value Kelley, NH_4-adsorbed uncorrected and corrected and the *S*-value Hissink. As will be seen from Table 4, there is some relation between the blank and the humus content of the soil. In the case of the soils very rich in humus, the blank reaches very high values.

As will be seen from Table 2, the corrected *S*-values of Kelley (NH_4-adsorbed) are a good deal smaller than the *S*-values Kelley-total bases and Hissink (28.9 − 22.3 − 29.4), except in the case of two very acid soils with not much humus, viz., B 2330 (3.8 − 3.8 − 3.7) and B 1697 (18.4 − 18.1 − 16.1). Two factors play a rôle here. In the first place some

hydrogen from the soil is replaced by NH_4; this makes the value NH_4-adsorbed greater than the value for total bases. The more acid the soils the more this factor will make itself felt. But I think, this influence will not be great, even in the case of very acid soils.

TABLE 4.—S-value as determined by Kelley's and Hissink's methods

Soil sample No. B	Per cent of organic matter (Table 1)	Milligram-equivalents			S-value Hissink (Table 2)
		Method Kelley NH_4-adsorbed, blank	S-value Kelley NH_4-adsorbed		
			Uncorrected	Corrected (Table 2)	
1690	23.1	7.0	29.3	22.3	29.4
1691	22.9	6.7	24.7	18.0	21.2
1718	48.2	12.1	73.9	61.8	76.2
1724	48.0	11.3	52.7	41.4	47.1
2145	45.4	19.2	64.5	45.3	61.1
2146	49.2	19.2	64.5	45.3	60.3
2329	5.0	2.3	6.1	3.8	4.0
2330	5.8	2.6	6.4	3.8	3.7
1698	9.7	5.7	30.8	25.1	30.4
1697	12.6	6.6	24.7	18.1	16.1
2335	1.5	0.3	33.8	33.5	37.4
2337	1.7	0.3	28.0	27.7	29.1
1937	8.5	5.3	39.8	34.5	48.0
1939	8.8	5.7	37.7	32.0	38.5
1944	2.2	2.1	20.2	18.1	29.5
1946	1.8	2.1	21.5	19.4	28.6

The second factor, which seems to me to be of much more importance, is that when the NH_4-soil is leached with distilled water, a peptisation of the NH_4-clay-humus formed takes place, especially in heavy clay and loam soils and in soils rich in humus, in consequence of which some NH_4-clay-humus-substance comes into colloidal solution, so that some NH_4 is leached out with the leaching water. The water leachates of the humus soils were more or less colored, whilst in the leachate of the clay soils there was present per 100 g. dried soil the following quantities of clay substance; B 2335, 1.74; B 2337, 0.48; B 1937, 0.47; B 1939, 0.29; B 1944, 0.34; B 1946, 0.49 g.

In consequence of the fact that some NH_4 is washed away, the value NH_4-adsorbed becomes smaller than the value total-bases. This latter factor makes itself felt especially in the case of soils rich in humus and clay; the less acid the soils are, the greater will be the effect of this factor; B 1718 (pH 5.90), for instance, with S-NH_4-adsorbed = 61.8 to S-Hissink = 76.2 and B 1724 (pH 4.58) with 41.4 to 47.1.

Bobko and Askinasi.—These methods were combined with the method of Gedroiz. With the method of Bobko and Askinasi the same remarks are to be made as with the method of Kelley NH_4-adsorbed. As a part of the hydrogen of the soil is replaced by the barium of the barium chloride, the S-values according to Bobko and Askinasi must be somewhat greater than the S-Hissink values and the more acid the soils are, the more this will be so. On the other hand, some of the barium adsorbed by the soil may be leached out with leaching water. As in the case of NH_4 this factor will make itself felt especially with heavy clay soils but in soils rich in humus, of a slightly acid to alkaline reaction, it will, however, be much less.

We therefore see a difference when comparing the two S-values (Hissink and Bobko-Askinasi) of the acid soils and the alkaline soils. For instance: B 1891 (pH 4.22): 29.4 smaller than 32.8; B 1946 (pH 7.56): 28.6 greater than 22.0; B 1718 (pH 5.90): $77.5 - 76.2 = 1.3$, and B 1724 (pH 4.58): $55.4 - 47.1 = 8.3$.

Gedroiz.—To obtain a neutral filtrate by leaching the soil with barium chloride solution the following quantities were required:

B 1690 and B 2330, 3 l.; for 1691 and B 1724, 4 l.; for the remaining 12 samples 2 l. of barium chloride solution. The correction for the barium chloride was determined in the following manner; 450 cc. $BaCl_2$ were put into a half liter flask, 3 cc. 0.02 N NaOH and 10 drops methyl orange were added; after standing overnight, the flask was filled with water to 500 cc., filtered, and 200 cc. of the filtrate was titrated to a certain tint. The soil extract was treated in the same manner and titrated to the same tint. Working in this way, a fairly good agreement was found between duplicate determinations.

The S-values according to Gedroiz (see Table 2, second column) are necessarily about as high as those of Bobko and Askinasi. For instance, with B 1690, Bobko and Askinasi find $S = 32.8$ and Gedroiz $= 4.0 + 29.4$ or 33.4.

In accordance with this, Gedroiz finds a positive titration value in the case of soils, where the S-Bobko-Askinasi is greater than the S-Hissink and a negative titration value in the case of soils, where the S-Bobko-Askinasi is smaller than the S-Hissink. Only in case soils have very small titration values according to Gedroiz, there may be some small deviations from this rule. The S-values, according to Kelley (total bases), Hissink, Bobko, and Askinasi, and Gedroiz will then be about the same; for instance; B 2335, 2337, and 1939.

Gedroiz says that the degree of saturation (or of unsaturation) of the soil is determined by his method. He supposes that by leaching the soil with barium chloride solution the barium replaces so much hydrogen that the treated soil reaches the *state of saturation.* B 1724, for instance, with $S=47.1$, adsorbs 11.2 me. barium from the $BaCl_2$ solution and its S-value becomes $47.1+11.2=58.3$. Gedroiz expresses the degree of saturation of this soil in the following terms:

$$\frac{47.1}{47+11.2}=\frac{47.1}{58.3}=0.81 \text{ or } 81 \text{ per cent.}$$

If these ideas of Gedroiz are right, then this peat soil B 1728 should be in a wholly saturated state, when containing $47.1+11.2=58.3$ me. bases adsorbed.

Now, a method for determining the saturated state of a soil must always give about the same result in the case of a given soil. This means the following: B 1718 and 1724 are the same soils, respectively limed and unlimed, and accordingly their S-values differ, being 76.2 and 47.1, respectively. But in the saturated state, both soils should have about the same S-values. This is not the case by using the Gedroiz method, which gives 78.4 and 58.3, respectively, the ratio between these two figures being 1.35.

The results, according to Gehring and Hissink, satisfy much better the above mentioned condition and so it is also the case with the S-values with a pH of 7 and with the S of the potential adsorption, as may be shown by the following data:

	S-values		
	B 1718	B 1724	Ratio
Gedroiz	78.4	58.3	1.35
Gehring	132.1	115.8	1.14
Hissink	272.4	296.0	1.08
pH 7	96.7	107.1	1.11
Potential adsorption	108.6	106.8	1.01

From the above it follows that the Gedroiz reagent only replaces from the soil a part of the hydrogen which is saturated by a base, and not only in the laboratory, but also in natural condition in the field.

Gehring's method.—Gehring prescribes the addition of 100 cc. of saturated $Ca(OH)_2$ to 25 g. of air-dried soil. Acid soils, rich in humus, such as B 1724, treated in this manner, gave with phenolphthalein no red color. In the case of B 1718, 1724, 2145 and 2146, therefore, 10 and 5 g. respectively air-dried soil and for the other samples 25 and 10 g. respectively were used. As shown in Table 2 the results depend largely on the amount of soil used. The leaching of clay-humus-soils with sodium chloride after

the treatment with calcium hydroxide takes a long time, apparently for the following reason. When treated with calcium hydroxide clay-humus-CaO is formed (adsorption), and is transformed by the leaching with sodium chloride into clay-humus-Na_2O, which peptizes a little.

With regard to the methods of Hutchinson-McLennan, Kappen and myself, I will merely remark that the results also depend on the ratio: grams clay-humus-substance to cubic centimeters of solution, whilst the concentration of the solution is also of influence. For the Gehring method this influence of the ratio is shown in Table 2. We could also observe fairly great differences with the Hutchinson method, by using more or less soil or a more or less concentrated bicarbonate solution. So far, we could find no time to study this subject for the Kappen method, but I suppose that the use of more or less soil will be of no great influence here, because Kappen uses a rather strong calcium acetate solution. As will be seen from Volume B (p. 187, Addendum), I have proposed in my own method to always use the same quantity of clay-humus-substance and because I use highly concentrated barium hydroxide solutions, my method is subject to only slight errors on this point.

Titration with CaO.—The titration with CaO took place as described in Volume A, p. 76 (shaken for 72 hours). The same remark about the influence of the proportion of soil to liquid can be made with regard to the results of the titration curves, but no further researches have been made on this subject.

It is recommended that the influence of the ratio: soil to liquid should be further investigated, and also theoretically considered for all the above mentioned methods.

Finally it should be noted that the value: *potential adsorption*, is not subject to this error.

Conclusions

The methods which have been tried, may be divided into two classes. The first class includes the methods for determining the amount of exchangeable bases, that is the value *S*. To this class belong the methods: Kelley (total bases) and Hissink, and, if you like, also the methods Kelley (NH_4-adsorbed) and Bobko-Askinasi.

The second class includes the methods for determining the amount of calcium oxide or barium oxide, which is adsorbed by the soil under certain conditions, either from a solution of a neutral salt (Gedroiz barium chloride) or from a solution of a salt of a weak acid (Hutchinson, calcium bicarbonate; Kappen, calcium acetate), or from a solution of calcium hydroxide (Gehring; titration-curves) or barium hydroxide (Hissink).

With the aid of the *S*-value and the amount of calcium oxide or barium oxide adsorbed by the soil, the degree of saturation of the original soil according to each different method can be calculated. Also from the

value—potential adsorption—a degree of saturation can be calculated. What I mean is shown in the following table in the case of soil B 1690 (See also Table 2):

TABLE 5.—Comparison of various methods for determining saturation

Method	*S* (Hissink)		Base adsorbed		Sum	Degree of saturation
Gedroiz	29.4	+	4.0	=	33.4	88
Hutchinson	29.4	+	9.5	=	38.9	76
Kappen	29.4	+	9.9	=	39.3	75
Gehring	29.4	+	11.0	=	40.4	73
Gehring	29.4	+	24.6	=	54.0	54
Hissink	29.4	+	107.5	=	136.9	22
pH=6	29.4	+	5.0	=	34.4	86
pH=6.5	29.4	+	10.8	=	40.2	73
pH=7	29.4	+	18.9	=	48.3	61
potent. ads.	29.4	+	21.2	=	50.6	58

From the above table it is clear that, when referring to the degree of saturation, it is always necessary to mention the method used.

Degree of Saturation According to Hissink (V-value)

My method for determining the degree of saturation ($V = 100\ S{:}T$) has been attacked on different grounds. Some are of the opinion that the strong solution of barium hydroxide would partly be transformed into barium carbonate by absorbing carbon dioxide either from the air or from the decomposition of the humus substances. Others have pointed out the possibility of the formation of basic salts.

My answer to these objections is in the first place that all the barium oxide which has been supplied with my method, remains in the soil in an exchangeable form. In the second place I wish to point out the following: Weak acids are saturated at very alkaline reaction; boric acid, for instance, by pH of about 10.5. We may, therefore, expect the weak acids present in the soil to be likewise saturated by a rather alkaline pH. Now I found that the reaction of soil suspensions containing as much barium oxide as is indicated by my T-S-value was very alkaline (pH about 10.5). In this very alkaline pH value at $V = 100$ I see a theoretical support of my method.

I was accordingly very pleased to hear in Dr. Truog's and Dr. Kerr's lecture that they found a pH of about 10.5 in the case of wholly saturated permutites also. In this connection I wish to refer to one of my papers in Volume A (p. 198), in which I pointed out that there is a certain relationship between the values pH and V.

There is a third point which supports my views and that is the results

which we get by calculating the equivalent weight of the humus-substance and of the clay-substance. I did this in the following manner: Soil B 1690 contains 23.1 per cent of organic matter, whilst $T = 136.9$; that means that 23,100 mg. organic matter are saturated by 136.9 me. bases; the equivalent weight of the organic matter being therefore 23,100: 136.9 = 169. And my various types of humus soils (without clay); sandy humus soils, low peat soils, high peat soils, all give an equivalent weight of the humus substance of about 170.

I may add that I found about the same equivalent weight for the humus-substance in a sample of Dappleriet (practically pure humic acid).

In my Faraday Society paper (2) I calculated the equivalent weights of the clay-substance in some clay soils, the average being 1250. I should be the last person to deny that the two figures (about 170 and 1250) are open to criticism and that they are only provisional.[1]

It has been contended that it was my intention to recommend liming the soil to such an extent that it would reach a degree of saturation (Hissink) = 100. My answer to this objection is that *all* the proposed methods merely determine certain values of the soil, which characterize the soil more or less, and that recommendations for the lime-requirement of the soil can be based only upon the results of these methods in conjunction with the results of field experiments.

That my V-value characterized the soil in a very good manner, may be shown by the following: the degree of saturation of the original soil B 1690 = 100 S: $T = 100 \times 29.4$: 136.9 (see Table 2) = 21.5 (see Table 1).

I have calculated the V-values of this soil after it has adsorbed as much calcium oxide as is indicated by each of the various methods. For instance, the V of B 1690 in the state of saturation, according to Hutchinson = 100×38.9: 136.9 = 28.4; according to Gehring (highest value) = 100×54.0: 136.9 = 39.4; with a pH of 7, $V = 100 \times 48.3$: 136.9 = 35.3 and according to the potential adsorption = 100×50.6: 136.9 = 36.9. These V-values for all the 16 soils are shown in Table 6. From these results we can draw the following conclusions:

A. Humus Soils (B 1690–B 2330).—First let us consider the first eight humus soils. It will then be seen that the 8 V-values according to Hutchinson, Kappen, with pH 7 and with the potential adsorption, agree fairly closely, so that average V-values may be calculated for these four columns. The V-values, according to Gehring, however, differ too much to enable one to calculate an average V-value.

[1] Although these values for the equivalent weight are only provisional, they do show very clearly that the humus-sustance has a far greater power of base-adsorption than the clay-sustance. This follows also from my K-values of the humus substance and the clay-substance. I found in the Dutch Soils which were in a practically well saturated state, under the natural climatic conditions in Holland, that 100 g. clay (I+II) contain about 1.1 g. CaO and 100 g. humus, about 5.0 g. CaO.

From this result I may draw the following conclusions: (1). For the tested types of humus soils, my *V*-value possesses a certain general significance and characterizes these types of humus soils very well; (2). The latter conclusions refer also to the results of the four methods: Hutchinson, Kappen, pH 7, potential adsorption. Judging from my results this latter statement cannot be made with regard to the Gehring methods. Further experiments, especially with regard to the proportion: soil (clay-humus-substance): CaO-solution may bring results that agree more closely with one another.

TABLE 6.—V-values as determined by various methods

(V, calculated with T-Hissink)

No. B	Original soil	Hutchinson	Kappen	With pH 7	Potential adsorption	Gehring (highest value)
1690	21.5	28.4	28.7	35.3	36.9	39.4
91	14.9	26.7	26.9	37.5	36.8	37.2
1718	28.0	31.2	31.4	35.5	39.9	48.5
24	15.9	25.2	25.0	36.2	36.1	39.1
2145	25.7	30.7	31.0	36.9	39.9	52.8
46	23.4	30.5	30.8	37.2	40.7	54.8
2329	11.9	26.4	25.2	36.8	40.4	77.4
30	9.7	27.3	25.7	39.9	41.2	79.5
Average humus soils		28.3	28.1	36.9	39.9	
1698	34.9	35.0	36.9	35.8	48.9	67.1
97	16.5	27.4	26.8	38.5	52.0	49.7
2335	50.9	52.9	52.8	52.8	61.2	69.1
37	41.9	51.7	48.8	42.0	64.4	68.0
1937	48.3		49.6		50.4	62.5
39	40.6	43.5	44.3	46.8	55.4	70.0
1944	53.2		54.3		55.9	60.5
46	53.1		54.4		66.1	64.6

B. Mineral Soils.—There are only four real mineral soils, with practically no humus, namely the clay soils 1944/46 and the loamy soil 2335/37. The *V*-values according to Hutchinson and Kappen for these soils are about 50 and 54; with pH 7 about 52 and 53; according to the potential adsorption about 56 and 64, and according to Gehring about 60 and 70.

These *V*-values are higher than the corresponding values of the humus soils. The result of this will be that for the four soils 1698/97 and 1937/39 with a fair amount of humus the corresponding *V*-values are between those of the humus soils and the mineral soils.

For the present I will confine myself to these few observations. More mineral soils have to be examined, before we can draw other conclusions with regard to these soils.

THE LIME-REQUIREMENT OF THE SOIL

I repeat that all of the proposed methods merely determine certain values of the soil, which characterize the soil more or less.

How far recommendations for the lime-requirement of the soil can be based upon the results of these methods, can be determined only with the aid of field experiments. As it was not my intention to treat these fertilization questions in my lecture, I will confine myself to the following remarks on this subject.

The question as to whether a soil must be limed is either a question of improving the structure of the soil (heavy clay soils) or relates to the acidity of the soil.

Heavy clay soils can have a slightly alkaline reaction, but nevertheless they may be in great need of lime for the improvement of their structure. Neither the method of Hutchinson nor that of Kappen, can tell us anything about the lime-requirement of these soils. The results of Gehring's method and of my own method, and also the potential adsorption can give us some indication of the necessary amount of lime of these heavy soils.

In Holland it is the custom to give these heavy clay soils, poor in humus, about 10,000 kg. CaO per ha. and somewhat less CaO for less heavy soils. From experience we know that under the Dutch climatic conditions, we must repeat this on heavy clay soils about every 12 or 14 years.

As for the other soils (sandy soils, sandy humus soils, humus soils) the results of all the proposed methods can be used for determining the lime-requirement of a given soil (and a given crop, under given climatic conditions), when the lime-requirement of this soil type (for the given crop, etc.) has previously been fixed with the aid of experimental fields. I will try to make my meaning clear.

Let us suppose that for a given humus soil (and a given crop under certain climatic conditions), the Hutchinson-Kappen methods give a fairly good indication of the lime-requirement of this soil. This means that the degree of saturation of this given soil (the V-value according to Hissink) must be brought up to about 28 (see Table 6, average humus soils). The lime which must be given per 100 g. of soil can then be calculated further from the S- and T-values of the original soil.

It may be said that the Hutchinson-Kappen methods are in any case simpler than the determination of the S- and T-values. This doubtless is the case, but the result of my researches, which are that the V-values according to Hutchinson and Kappen of the light tested humus soils are about the same (average 28.3, see Table 6), tends to give a wider scope to Hutchinson's and Kappen's results. It leads to the supposition that the results for one of the tested types of humus soils can be applied to the other types.

In this connection it is also important to state which pH the soil reaches, by absorbing so much calcium oxide as is found by the Hutchinson-Kappen methods. This pH can be fixed by the aid of the results of the titration curves (see Table 2).[1]

TABLE 7.—Comparison of Hutchinson's and Kappen's method on acid soil

No. B	*V* (Hissink)		
	Hutchinson	Kappen	pH about
1690	28.4	28.7	6.5
91	26.7	26.9	6.5
1718	31.2	31.4	6.5
24	25.2	25.0	6.5
2145	30.7	31.0	6–6.5
46	30.5	30.8	6–6.5
2329	26.4	25.2	6.5
30	27.3	25.7	6.5
1698	35.0	36.9	6.5
97	27.4	26.8	6–6.5
2335	52.9	52.8	6.5
37	51.7	48.8	6.5
1937		49.6	
39	43.5	44.3	6–6.5
1944		54.3	
46		54.4	

The above Table 7 shows that by a treatment according to Hutchinson and Kappen all the acid soils are brought up to a pH of about 6.5. In relation with the results of Table 5 we can also say that when saturating the humus soils to a degree of saturation (according to Hissink) = 28, the pH = 6.5. If, therefore, it has been established for a type of soil that the Hutchinson-Kappen method gives a good indication of the lime-requirement of this soil (for a given crop under certain climatic conditions), it can be further determined by a simple pH determination whether the soil is already in the required condition. So long as its pH lies below about 6 to 6.5, it is advisable to lime the soil. Of course the simple pH determination does not give any indication of the amount of calcium oxide which is necessary; this amount depends, amongst other things, on the humus content of the soil. Yet the determination of the pH before and after liming the soil is useful as is shown by the following consideration.

As I have already stated in my paper in Volume A: "What happens to the lime, when soil is limed," the object of liming the soil is to increase the amount of calcium oxide adsorbed by the clay-humus-substance.

[1] The pH which the soil reaches, according to Gehring, can be calculated in the same manner. As is known, by a degree of saturation (according to Hissink) = 100, the pH is about 10.5.

When liming the soil, this purpose is only partly accomplished; only a part of the given lime is adsorbed by the clay-humus-substance (see Volume A, Table E, p. 185). When liming, therefore, with the amount of lime found according to the Hutchinson-Kappen methods, then the pH 6.5 will generally not be reached and the pH determination enables us to state in how far a given amount of lime has been adsorbed by the soil. When this is not the case, we can later add more lime.

Potential Adsorption

Finally, I wish to point out the significance of the value: potential adsorption. The potential adsorption is the amount of CaO in grams that the clay-humus-substance of 100 g. of dried soil must adsorb, in exchangeable form, in order that there are contained 5 g. of CaO per 100 g. of humus and 1.1 g. CaO per 100 g. clay. As can be deduced from the results of the titration curves (see Table 2), the reaction of a soil in this state of saturation [K (humus) = 5.0 and K (clay) = 1.1] is about neutral to slightly alkaline.

For the clay soils the potential adsorption gives some indication of the amount of lime which should be given. So, for instance, for 1939 this value = 14.1 me. (see Table 2); which means that per 100 g. of soil the clay-(humus)-substance of the soil must adsorb $14.1 \times 28 = 394.8$ mg. CaO, or per ha. (3,000,000 kg.) 11,848 kg. CaO. For 1946 is calculated per 100 g. of soil $\times 3.8\ 28 = 106.4$ mg. CaO, or per ha. 3192 kg. CaO. This latter soil is therefore to be limed with at least 3192 kg. CaO, but while the lime, at least temporarily, remains in the soil partly in the form of $CaCO_3$, it is advisable to add more and, in this case of heavy clay soils, there is no objection to doing this.

With regard to the humus soils, we must be more careful with liming. Assuming that the humus soils must be brought to the saturation state according to Hutchinson or Kappen, it is necessary to lime with (28.2: 39.9) $\times$ the amount of the potential adsorption of these soils.

Further Researches

The main further researches are:

1. Comparison of the methods Gedroiz and Hissink for determining the values S in the case of soils containing calcium carbonate.

2. Influence of the blank with Kèlley's method (NH_4-adsorbed) in the case of humus soils.

3. Influence of the ratio soil: solution of and the concentration of the solution with the methods of Hutchinson, Kappen, Gehring, and Hissink.

4. Comparison of the results of laboratory methods for the determination of the lime requirement of soils with the results of field experiments of several years' duration. For the plan of these field experiments, see Dr. Christensen's proposals, Volume B, p. 81.

These remarks, together with what has been published in Volumes A and B, may serve as an introduction to a general discussion on base exchange and soil adsorption.

I only wish to point out that in discussing the matter we must clearly distinguish between facts and theories. And although we need theories, we must quite realize that they are only makeshifts which come and are doomed to pass away. Theories are only intended to give us an idea of the present state of our knowledge and a good theory should lead us as soon as possible to the domain where it does not apply without modification. We must try to bring our researches right up to this frontier. Only then can there be progress in our science.

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(1) Hissink, D. J. 1925. Trans. 2nd Commission of the International Soc. Soil Sci., Groningen (Holland), Vol. B.

(2) ———. 1924. Base exchange in soils, A general discussion held by Faraday Soc., Dec. p. 551.

Dr. Comber's report is included in his Secretary report of the Washington Meeting of Commission II. Unfortunately Dr. Lemmermann's report is unavailable for the Proceedings.

II. Preparation of Soil Extracts.—Conclusions concerning the uniform preparation of soil extracts with hydrochloric acid. Dr. A. A. J. de'Sigmond conducted an extensive investigation with the collaboration of Dr. E. Blanck and Dr. A. Rieser, Gottingen; Dr. P. L. Gile, Washington, D. C.; Dr. K. A. Vesterberg, Stockholm; and Dr. A. Seiwerth, Zagreb. Their detailed report follows:

CONCLUSIONS CONCERNING THE UNIFORM PREPARATION OF SOIL EXTRACTS WITH HYDROCHLORIC ACID

Dr. A. A. J. de'Sigmond, *President Commission III*

The brief history of the present cooperative work was given by the author at the Fourth International Conference at Rome, in 1924 (1). At this Conference the Second Commission adopted in principle the method of van Bemmelen and Hissink, as a conventional and simple method for preparation of soil extracts with concentrated hydrochloric acid. Only some particular details needed re-examination as to the ratio of soil to acid, and the time of boiling. This was the result of about 15 years of cooperative work in which all the leading methods, suggested for the preparation of soil extracts with concentrated hydrochloric acid were treated and discussed, especially at the first special meeting of the Second Commission at Munich in 1924 (2). I do not want to review the

great merit of the highly scientific discussions on the question; I may repeat only the conclusions of these transactions:

1. Though evidence was presented that the soil extract prepared with concentrated hydrochloric acid does not represent a natural limit of soil decomposition, the total analysis of the acid extract, supplemented by re-solution of the silica, decomposed and partly precipitated by the strong acid, by a dilute solution of alkali, will serve as a good guide in characterizing the soil types, especially if we investigate each typical horizon of the soil profile.

2. As the results of any method suggested by different authors seemed to give not absolute, but relative results, it appears rational to agree on a conventional method, which is quick and simple and gives uniform and accurate results.

These were the reasons that led the members of the Commission to accept at Rome the principles of the van Bemmelen-Hissink method, which is relatively rapid and simple and gives uniform and exact results. But as a number of the members had some doubt as to whether the proposed ratio of soil to concentrated hydrochloric acid (10g.: 250 cc.) was somewhat too wide, and that the boiling of two hours could be shortened to one hour, the Second Commission decided that, before making a definite decision as to these details, we should study these two particular points exclusively and the author, as referee of this question, was authorized to initiate cooperative experiments along this line.

By virtue of this authority I engaged and asked numerous soil scientists to devote attention to our line of work, and about 18 to 20 first class men promised to test the four different soil samples collected by Dr. Novák (Brno) (podsol and rendzina), Dr. Joseph (Sudan) (badob soil) and by the author (alkali soil). These soil samples were the same as those for comparative mechanical analysis.

In order to make the analytical part as simple as possible, I proposed to determine only the silica soluble in concentrated hydrochloric acid and 5 per cent potassium hydroxide and the crude total iron and aluminum precipitated simply with ammonia. I was aware that the latter determination does not give the exact amount of aluminum and iron since phosphoric acid, titanic acid, etc., may precipitate also. Therefore in soil analysis we generally use the acetate method to precipitate the $Al_2O_3+Fe_2O_3+P_2O_5$. However, as this method is not as simple as the former, and itself requires particular study and control, and as it was not the aim of these investigations to determine the exact quantity of each compound, but only to see whether the variation of the ratio of the soil to concentrated hydrochloric acid, as well as the shortening of the time of boiling, would materially affect the degree of decomposition of the soil sample, by the standard concentrated hydrochloric acid of 1.100 sp. gr., these reasons were determinant in simplifying the task to be accomplished.

I had in mind that, of the members of the Commission who would take part in this cooperative work almost all were professors engaged in soil research, and were hardly provided with proper assistance for purely analytical work.

Unfortunately in spite of these simplifications a considerable number asked to be excused, as they were not in a position to carry out the analyses

TABLE 1.—Total SiO_2 soluble in concentrated hydrochloric acid and 5 per cent potassium hydroxide

Soil	Treatment [a]	Budapest de'Sigmond	Göttingen Blanck and Rieser	Groningen Hissink	Stockholm Vesterberg	Washington Gile	Zagreb Seiwerth
		per cent	per cent	per cent	per cent	per cent	per cent
	1	9.90		10.61	9.05		9.63
Alkali	2	10.43		11.49		11.14	10.44
	3	9.75		10.43		10.36	10.39
	4	10.25	13.29	11.47	9.17	11.52	10.86
	1	29.82			26.18		30.93
Badob	2	29.90				30.70	31.02
	3	30.28				30.28	31.02
	4	30.20	23.25	27.00	27.32	31.05	30.85
	1	17.89			17.57		17.63
Podsol	2	17.71				19.70	18.42
	3	18.75				16.46	19.17
	4	18.61	17.77		19.21	19.02	20.01
	1	9.45			8.86		8.67
Rend-	2	9.19					9.81
zina	3	9.67				10.11	9.29
	4	9.44				9.28	9.92
			9.63		9.09	10.01	

[a] 1. Soil : acid = 1 : 10, 1 hr. boiling.
2. Do 2 hr. Do
3. Soil : acid = 1 : 25, 1 hr. Do
4. Do 2 hr. Do

because of other urgent researches, or lack of necessary assistance. This is the reason, that in the following tables we find the analytical results of only a few, but well known, soil laboratories and soil scientists. Nevertheless, as the results agree fairly well, and it does not seem to me worth while to persist longer with these details I think we can draw our conclusions and then proceed to further particulars, which require greater uniformity. In the appendix of the report we may find all the data of the single investigators. I should point out, however, that the control analyses of the same laboratory, made by different investigators, agree

very well, proving that the analytical results can be relied upon. Moreover, we might notice from the figures of Tables 1 and 2, that apart from some exceptional discrepancies, all the data of the different laboratories agree fairly well with each other. In the cases where the Al_2O_3 and Fe_2O_3 were determined separately by the acetate method, I found it necessary to add the TiO_2 and P_2O_5 so as to make the values equivalent to the totals of $Al_2O_3+Fe_2O_3$ determined simply by precipitation with ammonia. It is true that the titanic acid, with some phosphoric acid, may precipitate with the silicic acid, but as some of the investigators determined the above mentioned compounds separately, I found it the most adequate to add the TiO_2 and P_2O_5 to the $Fe_2O_3+Al_2O_3$.

TABLE 2.—Total $Al_2O_3+Fe_2O_3$ (P_2O_5, TiO_2, Mn_3O_4)

Soil	Treatment [a]	Budapest de'Sigmond	Göttingen Blanck and Rieser	Groningen Hissink	Stockholm Vesterberg	Washington Gile	Zagreb Seiwerth
		per cent	per cent	per cent	per cent	per cent	per cent
	1	8.50		8.41	8.21		8.55
Alkali	2	8.64		9.01		9.25	9.23
	3	8.61		8.48		8.58	9.05
	4	8.92	8.11	9.19	8.83	9.35	9.76
	1	22.52			21.23		22.06
Badob	2	22.70				21.70	23.14
	3	22.73				22.08	22.95
	4	22.86	24.21		23.59	22.97	23.77
	1	18.31			17.09		18.02
Podsol	2	18.22				18.99	18.60
	3	18.49				18.00	18.66
	4	18.77	18.91		20.91	18.90	18.78
	1	6.71			6.77		6.56
Rend-	2	7.01					7.54
zina	3	7.54				7.46	7.27
	4	6.91				6.66	7.88
			6.62		8.78	7.25	

[a] 1. Soil : acid=1 : 10, 1 hr. boiling.
2. Do 2 hr. Do
3. Soil : acid=1 : 25, 1 hr. Do
4. Do 2 hr. Do

Surveying the figures of Tables 1 and 2 we must state that, if we eliminate some evident deviations indicated in the tables with a question-mark,[1] the analytical results of the different laboratories agree satis-

[1] Editor's note: These doubtful results were not indicated in the tables accompanying the manuscript.

factorily. The referee had no time to inquire as to the specific causes of the eliminated analytical deviations, though it would have been very instructive to find the reasons for these discrepancies. I am also sorry to state that the full task was carried out completely only in two laboratories. Nevertheless, the other results are still valuable and indicate that the cooperative work, though limited in quantity, was very successful in quality. In Tables 3 and 4, I have compiled the average values (D), the average deviation from the average value (*d.f.*), average error of the average value $\left(\frac{d.f.}{\sqrt{n}}\right)$ and the probable deviation of the average (*w.f.*), calculated by using any single analysis of the enclosed reports of each laboratory, according to the mathematical formulas in the book of Ostwald-Luther (3). This proved that for the best agreement the above-indicated figures should be excluded. The figures of Tables 3

TABLE 3.—Average results of cooperative determination of SiO_2

Soil	Treatment [a]	D	n = number of the single analyses	d.f.	$Df=\frac{d.f.}{\sqrt{n}}$	w.f. = 4/5 d.f.
	1	9.79	6	0.416	0.169	0.333
Alkali	2	10.74	6	0.527	0.215	0.421
	3	10.28	8	0.390	0.137	0.312
	4	10.73	8	0.650	0.229	0.520
		(11.02)	(9)	(0.829)	(0.276)	(0.664)
	1	30.13	4	0.677	0.338	0.541
		(29.54)	(5)	(1.462)	(0.654)	(1.170)
Badob	2	30.50	5	0.628	0.223	0.503
	3	30.56	7	0.508	0.192	0.407
	4	30.73	7	0.358	0.135	0.287
		(29.53)	(9)	(1.888)	(0.629)	(1.510)
	1	9.02	5	0.344	0.154	0.272
Podsol	2	9.62	5	0.406	0.182	0.325
	3	9.23	7	0.341	0.129	0.273
	4	9.56	8	0.363	0.128	0.284
	1	17.73	5	0.456	0.204	0.365
Rendzina	2	18.39	5	0.394	0.176	0.315
	3	18.88	6	0.173	0.0706	0.138
	4	19.03	9	0.576	0.192	0.465

[a] 1. Soil : acid = 1 : 10, 1 hr. boiling.
2. Do 2 hr. Do
3. Soil : acid = 1 : 25, 1 hr. Do
4. Do 2 hr. Do

and 4 enclosed in parentheses represent the corresponding results where all figures participated in the calculation without any exclusion.

TABLE 4.—Average results of cooperative determinations of $Al_2O_3+Fe_2O_3$

Soil	Treatment[a]	D	n= number of the single analyses	d.f.	$Df=\frac{d.f.}{\sqrt{n}}$	w.f.= 4/5 d.f.
Alkali	1	8.50	6	0.183	0.0747	0.146
	2	9.02	6	0.256	0.105	0.205
	3	8.78	8	0.197	0.0697	0.158
	4	9.16	9	0.410	0.137	0.328
Badob	1	22.28	5	0.250	0.112	0.200
	2	22.82	5	0.546	0.244	0.437
	3	22.75	7	0.480	0.181	0.384
	4	23.46	8	0.541	0.241	0.433
Podsol	1	17.98	5	0.358	0.160	0.286
	2	18.56	5	0.270	0.121	0.216
	3	18.47	7	0.244	0.0922	0.195
	4	19.18	7	0.562	0.212	0.450
Rendzina	1	6.70	5	0.256	0.114	0.205
	2	7.36	5	0.272	0.122	0.218
	3	7.23	7	0.257	0.0971	0.206
	4	7.57	8	0.617	0.223	0.494

[a] 1. Soil : acid= 1 : 10, 1 hr. boiling.
2. Do 2 hr. Do
3. Soil : acid= 1 : 25, 1 hr. Do
4. Do 2 hr. Do

Considering the partial conclusions of the individual investigators as presented in the Appendexes we may accept the following general conclusions:

1. As a whole we may conclude from the cooperative work of the members of the Second Commission, that in most cases where the ratio of soil to acid was 1:25 and the time of boiling two hours, the dissolved material was somewhat greater than in the case of soil to acid ratio of 1:10 and boiling but for one hour. The average differences ran as follows:

Soil	*I*	*II*	*III*	*IV*	*Av. difference*
SiO_2	0.94	0.60	0.80	0.54	0.720
$Al_2O_3+Fe_2O_3$	0.66	1.18	1.20	0.87	0.977

2. In most cases the length of boiling had more effect than the ratio of the soil to acid. The average differences between one and two hours' boiling were as follows:

Soil	*I*	*II*	*III*	*IV*	*Av. difference*
SiO_2	0.33	0.27	0.40	0.46	0.365
$Al_2O_3+Fe_2O_3$	0.45	0.62	0.64	0.50	0.552

3. The results of the experiments with a soil to acid ratio of 1:25 and one hour boiling sometimes closely approach those with a 1:10 ratio and two hours' boiling, but we have contrary evidence as well.

4. The analytical results of the different laboratories and analysts, in cases where the ratio of soil to acid was but 1:10, and the time of boiling but one hour, though giving in most cases somewhat lower figures, agree very well with each other, proving that the supposed discrepancies caused by the 10 to 15 minutes' preliminary boiling off of the surplus hydrochloric acid did not appear. We have no reason for not accepting these terms as they represent about the least decomposition of the soil by concentrated hydrochloric acid and are the most economical of time, chemicals and fuel, consequently the more expeditious for practical use. Only in cases where the soil is very high in carbonates or other mineral matter attacked by acid is it advisable to use the 1:25 ratio of soil to acid. But as the deviations with soil to acid ratios of 1:10 and 1:25 and one hour boiling are in both cases very slight it makes practically no material difference whether we use the one ratio or the other.

Now before coming to the final proposition which I should be pleased to submit to the Second Commission for approval and decision, I may treat some particular observations of the analysts, who took part in the experimental work.

At first in our decision we should adhere strictly to the principles of the method, such as the time of boiling, the ratio of soil to acid, the strength of acid and the principles of redissolving the silica decomposed and precipitated by the strong acid. In the main we should accept also the general principles of the mode of treatment. However since, as we may see below, some analytical details require more precise description or further analytical study not convenient to handle in different laboratories, we should not take final action on these details but we should charge the State Laboratory for Soil Science at Groningen, Holland, and Dr. D. J. Hissink, as director of the aforesaid laboratory, and as one of the authors of the van Bemmelen-Hissink method, with more precise description of the method, taking into consideration the principles proposed below and remarks of the analysts who cooperated in this line of work. The copies of the original reports are included in the appendexes and in them we may find all details and suggestions, which we might use for the elaboration of the description of the method.

RECOMMENDATION

The Second Commission of the International Society of Soil Science accepts as a provisional international method for preparation of the soil extract with concentrated hydrochloric acid the van Bemmelen-Hissink method based on the following final principles:

1. A ratio of soil to acid of 1:10, but if the soil is rich in carbonate or other acid-attackable compounds, that of 1:25.
2. The strength of the acid should be 20 per cent (by weight) i.e., of sp. gr. 1.100 which boils at 110° C. without changing the concentration of the hydrochloric acid.
3. Boiling time one hour calculated from the time when the constant boiling point (110° C.) is reached. The preliminary heating should not take longer than 10 to 15 minutes.
4. In order to dissolve the so-called soluble silica, which comes from the decomposition of the silicates by the treatment with hydrochloric acid, but which is in its greatest part reprecipitated by the concentrated hydrochloric acid and evaporation to dryness, we adopt the treatment of the dry residue with 200 cc. of potassium hydroxide, sp. gr. 1.04, for 5 minutes at 55° C.
5. Dr. D. J. Hissink, director of the State Laboratory of Soil Science, at Groningen, Holland, as one of the authors of the original method, will be charged with the description, in every particular, of the details of the process; taking into consideration as far as possible, the remarks of the members who took part in the cooperative work, but in such a way that the full description should be available with the edition of the transactions of the First Congress. If some uncertain details should occur, requiring more comprehensive experiments or discussions, this event should not cause any delay in the publication of the method in the transactions, but will be studied, and if settled, reported and published afterwards. In this way there will be time and opportunity for each member of the Commission to test and examine the provisionally accepted method in each detail and report his criticisms to Dr. Hissink, until at the next Congress, we will be in a position to adopt the provisional method as a final official method of the International Society of Soil Science.

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APPENDIX I

Report of the Soil Laboratory of the University of Technical Sciences, Budapest, Hungary

Dr. A. A. J. de'Sigmond

The four soil samples of the Second Commission were analyzed according to the instructions of the Commission. Each analysis was repeated by two different analysts and the respective results are collected in Table 1.

TABLE 1.—Analytical results

Soil		Soil : acid = 1:10 1 hr. boiling		Soil : acid = 1:10 2 hr. boiling		Soil : acid = 1:25 1 hr. boiling		Soil : acid = 1:25 2 hr. boiling	
Alkali	HCl – sol. SiO_2	0.11	0.14	0.16	0.12	0.24	0.18	0.22	0.21
	KOH – sol. SiO_2	10.10	9.46	10.94	9.64	9.87	9.21	10.23	9.85
	Total sol. SiO_2	10.21	9.60	11.10	9.76	10.11	9.39	10.45	10.06
	Av. Do	9.90		10.43		9.75		10.25	
	$Al_2O_3+Fe_2O_3$	8.46	8.54	8.92	8.36	8.51	8.72	8.84	9.01
	Av. Do	8.50		8.64		8.61		8.92	
Badob	HCl – sol. SiO_2	0.29	0.31	0.27	0.35	0.33	0.24	0.32	0.28
	KOH – sol. SiO_2	30.09	28.96	27.68	30.50	29.30	30.69	29.22	30.58
	Total sol. SiO_2	30.38	29.27	28.95	30.85	29.63	30.93	29.54	30.86
	Av. Do	29.82		29.90		30.28		30.20	
	$Al_2O_3+Fe_2O_3$	22.20	22.85	22.80	22.60	22.30	23.17	22.65	23.08
	Av. Do	22.52		22.70		22.78		22.86	
Podsol	HCl – sol. SiO_2	0.24	0.22	0.18	0.17	0.21	0.19	0.18	0.20
	KOH – sol. SiO_2	16.97	18.36	17.13	17.95	18.47	18.66	18.40	18.45
	Total sol. SiO_2	17.21	18.58	17.31	18.12	18.68	18.85	18.58	18.65
	Av. Do	17.89		17.71		18.75		18.61	
	$Al_2O_3+Fe_2O_3$	18.08	18.55	18.21	18.24	18.57	18.42	18.92	18.62
	Av. Do	18.31		18.22		18.49		18.77	
Rendzina	HCl – sol. SiO_2	0.21	0.18	0.14	0.15	0.27	0.16	0.16	0.15
	KOH – sol. SiO_2	9.64	8.87	8.87	9.22	9.12	9.79	9.50	9.08
	Total sol. SiO_2	9.85	9.05	9.01	9.34	9.39	9.95	9.66	9.23
	Av. Do	9.45		8.19		9.67		9.44	
	$Al_2O_3+Fe_2O_3$	7.05	6.38	7.28	6.75	7.11	7.97	6.95	6.87
	Av. Do	6.25		7.01		7.54		6.91	

The figures of Table 1 prove that the parallel analyses agree satisfactorily, especially when we consider that the titanic acid was not determined and may cause slight disturbances in the analytical results.

Procedure in the Experiments

In each case a 10 g. sample of air-dry soil was used for one analysis. This was treated in an open flask, according to the scheme of the ex-

periments, with either 100 or 250 cc. of 25 per cent (by weight) hydrochloric acid and heated quickly over a free gas flame with continual agitation until the constant boiling point, 110° C., was reached. This required as a rule hardly more than 5 minutes. But we may note that this heating over a free gas flame demands much care and practice and not uncommonly jeopardizes the flask and the whole analysis. Therefore, the use of good glassware (we use Jena glass) is urgently recommended. For general use it seems to us advisable to find a safer mode of procedure.

After the right boiling point (110° C.) was reached we fitted the reflux condenser to the flask and continued the boiling in an oil bath or a suitably diluted bath of sulfuric acid for the desired 1 or 2 hours. The constant boiling over an open gas-burner was dispensed with because in doing routine analyses the constant care of the set was inconvenient. After the elapse of the boiling time, we added cold water, diluting the whole content of the flask to about 450 cc., and allowed the insoluble part to settle, as a rule until the next day. Then the clear solution was decanted through a filter and the residue washed repeatedly with pure water, until the washings were but slightly acid. As the proposed addition of a little sodium chloride might introduce some difficulties in the determination of alkalies, we adopted the use of Jena quartz filters which proved very satisfactory and rapid, as the filtering could be accelerated by suction. If this is not available we would propose the use of pure ammonium chloride or ammonium nitrate instead of sodium chloride, to remove the last traces of acidity. The whole amount of the solution (*B*) was used for the determination of silica soluble in concentrated hydrochloric acid, and the total iron and aluminum.

The insoluble residue (Residue *A*) on the filter was added to the rest in the flask, evaporated and dried at 105° C. The proposed treatment of the whole residue with alkali may be accurate but it is more convenient to use but a fraction of the whole, about a third, and another third for the ignition, and possibly for the determination of titanic acid and phosphoric acid precipitated with the silica.

The weighed quantity of dry residue was treated for 5 minutes at 55° C. with 200 cc. of potassium hydroxide, sp. gr. 1.04, in an Erlenmeyer flask and well stirred. After the 5 minutes heating it was instantly cooled by adding about 250 cc. of cold water. After settling, the clear solution was decanted through a filter and the residue washed until the disappearance of alkaline reaction. In this case we added finally some pure sodium chloride, to prevent dispersion of the precipitate, since here the quartz filter is not recommended on account of the possibility of its being attacked by the alkali solution, and the determination of alkalies is not desired.

In the alkali solution we precipitate the silica by adding hydrochloric acid in excess, evaporating to dryness, and adding again a few drops of

concentrated hydrochloric acid to it. After about 10 to 15 minutes digestion at laboratory temperature we dilute with 100 cc. of water, boil to coagulate the silica and then allow to settle. The clear solution is decanted through a filter, the precipitate washed 3 to 4 times with hot water by decantation, then poured onto the filter and washed until the chloride reaction disappears. As the filtrate contains some (about 5 per cent of the total silica) silicic acid, the solution must be evaporated again and digested 1 to 2 hours; then, adding a few drops of hydrochloric acid after 10 to 15 minutes standing, we pour hot water on it, filter and wash. According to Hildebrand the filtered solution contains but a very slight amount of silica, at the most 0.15 per cent of the total, generally even less. In this solution we may determine the alumina which is as a rule not considerable. This direct determination of the alkali-soluble silica takes considerable time and still it is not free from errors, because the titanic acid and phosphoric acid are partly precipitated by the concentrated hydrochloric acid solution and accompany the silica as far as its final precipitation. If we want to know the exact amount of silica we must previously determine the titanic acid and the phosphoric acid, in the ignited precipitate or in a fraction of the residue (A) as mentioned before.

If we want a quicker procedure we may use the indirect determination of the soluble silica. Since the residue (A) of the acid treatment consists of undecomposed minerals (a), alkali-soluble silica accompanied by some alumina, titanic acid and phosphoric acid (b), and some organic matter (c), if we determine in one fraction the organic matter (c) by ignition, in another fraction the residue of the alkali treatment after ignition (a), by difference we get the soluble silica with its companions, as $b=A-(a+c)$. For routine analyses we have found this indirect method more convenient and yet satisfactory, and if desired the amounts of Al_2O_3, TiO_2, P_2O_5, etc., accompanying the silica may be determined separately in another fraction of the residue. In the case of the figures treated above we always used the direct method.

In solution B we have still some silica and organic matter. For that reason we evaporate the whole solution to dryness after adding about 20 to 25 cc. of concentrated nitric acid and repeat this treatment until the organic matter is completely oxidized. Then we add about 20 to 25 cc. of concentrated hydrochloric acid to expel all nitric acid, which would interfere with the alkali determination. This treatment may be repeated about twice to completely dehydrate the silica and finally we heat it for about 3 to 4 hours in an oven at 120° C. Then after adding some concentrated hydrochloric acid we digest about 10 minutes and continue the treatment as before with the silica. We may notice however that this precipitate also can be contaminated with some titanic and phosphoric acid. This silica may be added to the alkali-soluble

silica and represents the silica decomposed by the acid treatment and the amorphous silicic acid present in the soil. The latter can be determined if we treat the original sample with 5 per cent potassium hydroxide as described before.

In the solution filtered off from the silica we made the determination according to the directions of the Commission by repeatedly precipitating the bulk of alumina and ferric oxide with ammonium hydroxide and treating as the total iron and aluminum. Although some titanium, phosphorus, manganese and calcium may precipitate also, in this case the inaccuracy did not impair the aim of the experiments, as the agreement of parallel analyses obviously proves. Nevertheless, in ordinary cases we employ the following treatment:

After the precipitation of silica and filtration of the acid soil extract (B) we bring the volume of the solution to 500 cc. with wash water, and take, for the determination of Al_2O_3, Fe_2O_3 (TiO_2, P_2O_5), MnO, CaO and MgO, 100 cc. (B_1); for the determination of SO_3, K_2O and Na_2O, 100 cc. (B_2); and for the determination of P_2O_5 another 100 cc. (B_3).

Analysis of B_1 to determine the Al_2O_3, Fe_2O_3 (TiO_2, P_2O_5), MnO, CaO, and Mg

The solution is heated to boiling, then neutralized by carefully adding sodium carbonate solution and stirring so as to reach the neutral point; then after adding 25 cc. of 10 per cent sodium acetate solution and acidifying with acetic acid, we boil the solution to precipitate the basic salts of iron and aluminum acetate. The precipitate settles rapidly and should be filtered instantly, hot as it is, and washed with dilute sodium acetate until the chloride and calcium reactions disappear.

The precipitate contains besides Al_2O_3 and Fe_2O_3, the total P_2O_5 and TiO_2, which were not previously precipitated with the two fractions of SiO_2. Some traces of manganese will precipitate too, but the bulk of it is to be found in the filtrate.

The acetate precipitate is again dissolved with hot 10 per cent hydrochloride acid and repeatedly precipitated with pure ammonia, washed with hot water, redissolved, and re-precipitated with ammonia, so as to get all the manganese into solution, which should be added to the original solution for manganese. The ammonia precipitate is dried, ignited and weighed, and contains $Al_2O_3+Fe_2O_3+TiO_2+P_2O_5$. As a rule we have neglected the determination of the titanium on account of the difficulties and limited amount. In this case the ignited precipitate was used to determine iron by reduction to $FeSO_4$ and titrating with potassium permanganate. In the B_3 fraction of the solution we determined the phosphoric acid. If however, the qualitative tests showed that the amount of titanium was considerable we determined the titanic acid in the ignited precipitate as a continuation of the iron determination.

In this case we fuse the ignited precipitate with potassium pyrosulfate, dissolve it in dilute sulfuric acid and filter the solution, which may contain a precipitate of silica. Now, passing hydrogen sulfide into the filtrate, we determine the iron by titration according to the method of Margueritte. After that we concentrate the solution by evaporation and make up to a volume of 100 cc. with approximately 5 per cent sulfuric acid. In this solution the titanium is determined colorimetrically according to Weller. This method was seldom used, therefore we cannot speak of it as a controlled and adopted method. We quote only the authors.

The manganese is determined in the collected hydrochloric acid solutions and combined wash waters. After adding some more hydrochloric acid we treat with an excess of pure ammonia solution to obtain an alkaline solution in which eventually some aluminum and iron may precipitate. If such is the case we filter, wash, and after redissolving the precipitate with hydrochloric acid it should be added to the stock solution of the acetate precipitation. To the filtrate or clear alkaline solution we now add enough bromine water to produce a yellow color. After this we make alkaline again with ammonia and heat it to boiling. By this procedure a precipitate of mangano-manganite is formed which includes some calcium manganite. We filter and dissolve the precipitate in hot hydrochloric acid. After diluting we precipitate the manganese with ammonia and freshly prepared ammonium sulfide, allowing about 24 hours to settle. After filtering off the manganosulfide precipitate, we wash with dilute ammonia, ignite the dried precipitate and weigh as Mn_3O_4. By multiplying this with the factor 0.93 we calculate the result to MnO.

The calcium is determined in the combined filtrates of both manganese precipitations. The whole is evaporated to dryness, dissolved in dilute hydrochloric acid, made alkaline with ammonia, and, to prevent any precipitation of magnesium oxalate we acidify with dilute acetic acid, boil, and precipitate with ammonium oxalate. After digesting for about four hours on a water bath we filter and wash with dilute ammonium oxalate solution, and determine as CaO by igniting the dried precipitate.

To the filtered solution we add dilute ammonia in excess and precipitate the magnesium with sodium phosphate. After about 24 hours settling, we filter, wash with 5 per cent ammonia and determine it as magnesium phosphate.

2. Analysis of B_2 to determine the SO_3, K_2O and Na_2O_3

We precipitate in a boiling acid solution with hot, approximately 10 per cent, barium chloride, digesting 15 minutes on the water bath. After 24 hours settling we filter, wash with dilute hydrochloric acid, dry and ignite the precipitate, and weigh the $BaSO_4$.

The filtrate from the barium sulfate precipitate is evaporated to dryness on the water bath and heated about half an hour more on a sand bath. Now after adding 200 cc. of warm water we carefully titrate it and, adding alkali-free barium hydroxide solution digest it on the water bath about half an hour. Now we filter and wash the precipitate with hot water until we get about 1 liter of solution. This we evaporate to about 200 cc. and after adding to it dilute ammonia and pure ammonium carbonate solution we digest again half an hour on the water bath. The precipitate is filtered and washed, and the filtrate evaporated to dryness. Now we volatilize the ammonium salts and dissolve the dry residue in some water. Adding a few drops of ammonia and ammonium carbonate

TABLE 2.—Analyses of hydrochloric acid extract of alkali soil

	Analyst A	Analyst B
	per cent	per cent
Na_2O	0.36	0.48
K_2O	2.35	2.15
CaO	0.70	0.80
MgO	0.72	0.64
Fe_2O_3	3.03	3.41
Al_2O_3	5.75	5.45
SO_3	0.30	0.20
P_2O_5	0.16	0.10
CO_2		
SiO_2 sol. in concd. HCl and 5% KOH	10.38	10.74
Loss on ignition	1.72	2.20
Insoluble	71.61	71.40
Moisture	3.10	2.94
Total	100.18	100.51

we again get some precipitate. We filter, wash and fuse again, and repeat this procedure as often as we still get more turbidity by adding the ammonia and ammonium carbonate to the redissolved salts. After we no longer get any precipitate, we evaporate the solution two or three times with hydrochloric acid and weigh the slightly ignited salts as KCl+NaCl.

In this mixture we determine the potassium as platinate in the usual way.

Both standard methods are accurate but take much time and are expensive. It would be well to study a quicker and cheaper method.

In the solution B_3 we determine the phosphoric acid in the ordinary way, precipitating with ammonium molybdate according to Lorenz or redissolving the molybdic precipitate and precipitating again with magnesia mixture. In the presence of appreciable titanium, we encounter some difficultues but this question should be studied more exactly.

As this mode of procedure has proved satisfactory in our laboratory I

described it as material for further study and discussion. As an example of the agreement between the complete results by two analysts, I may quote in Table 2 the complete analysis of the concentrated hydrochloric acid extract of the alkali soil of the International Commission.

APPENDIX 2

Vergleichende Untersuchungen über Bodenauszüge nach der Salzsäure-Methode, ausgeführt im Agrikulturchemischen und Bodenkundlichen Institut der Universität Göttingen von Prof. Dr. E. Blanck und Dr. A. Rieser

Die vier eingesandten Bodenproben aus *Ungarn* (Szik-Boden), *Aegypten* (Badob) und *Böhmen* (Podsol und Rendzina) wurden einmal genau nach der Vorschrift (Methode *A*), so dann nach unserer eigenen Methode (Methode *B*) und ferner vorbereitet nach *A*, aber analysiert (1) nach *B* (Methode *C*) und (2) Trennung der Sesquioxide von CaO mit frisch gereinigtem Ammoniak durch doppelte Fällung (Methode *D*) untersucht.

Die Methode wurden wie folgt ausgeführt:

Methode A: genau nach der Vorschrift der II. Internationalen Kommission über chemische Bodenuntersuchung.

Methode B: 10 g. Boden werden mit der 5-fachen Menge einer 10%-igen Salzsäure 4 Stunden bei Wasserbad-temperatur gehalten. Die SiO_2 wird abgeschieden und im Filtrat die Sesquioxide durch Hydrolyse mittels Natriumacetat von CaO und MgO getrennt. Zur Bestimmung der laugelöslichen SiO_2 wird der Rückstand mit der 5-fachen Menge einer 5 %-igen Sodalösung 15 Minuten lang bei 55° (Wasserbad) behandelt und im Filtrat die SiO_2 durch Salzsäure wie gewöhnlich abgeschieden. Die Trennung der Sesquioxide von CaO erfolgt nach der Natriumacetatmethode.

Methode C: Salzsäureauszug nach der Methode *A*, Analyse aber nach Methode *B*, Trennung der Sesquioxide mit Natriumacetat.

Methode D: Auszug nach *A*, Analyse ebenfalls, aber Trennung der Sesquioxide von CaO mit Ammoniak, frisch gereinigt, durch doppelte Fällung.

Die gefundenen Mittelwerte sind in Tabelle 1 zusammengefasst.

Vergleicht man *A* mit *B*, so zeigt sich, dass *A* mehr ein *Aufschluss* als ein *Auszug* ist, denn der Silikat komplex ist zum grössten Teil durch die Lauge zerstört worden. Dennoch ersieht man, dass eine so starke Säure wie die benutzte gar nicht notwendig ist, da die 10 %-ige Säure fast ebenso viel wie die konzentrierte in Lösung bringt. Starke Bedenken bestehen aber gegen die Benutzung der vorgeschriebenen Trennung der Sesquioxide von CaO etz. mit Ammoniak in der Hitze. Die Menge der Tonerde (Al_2O_3) erscheint zu hoch, wogegen Kalk (CaO) und Magnesia (MgO) zu niedrig ausfallen. Dies tritt besonders dann in Erscheinung

TABELLE 1.—Vergleichende Resultate der vier Methoden

Boden	Methode	SiO_2 laugelöslich	SiO_2 HCl-löslich	Al_2O_3 laugelöslich	Al_2O_3 HCl-löslich	Fe_2O_3	CaO	MgO	P_2O_5
Ungarn	A	13.08	0.21	0.21	4.44	3.59	1.32	0.07	0.08
	B	1.22	0.16		3.28	3.28	0.55	0.64	0.08
	C				3.71	3.58	0.57	0.93	0.08
	D				3.75	3.58	0.74	0.50	0.08
Aegypten	A	22.89	0.36	0.25	14.92	8.87	4.28	0.10	0.42
	B	1.25	0.22		8.09	7.03	3.99	2.37	0.42
	C				10.85	8.87	6.11	2.33	0.42
	D				15.59	8.87	3.24	0.63	0.42
Podsol	A	17.45	0.32	0.27	12.18	6.26	0.47	0.35	0.37
	B	1.83	0.24		5.53	5.34	1.91	1.51	0.33
	C				10.49	6.26	1.01	1.73	0.37
	D				11.04	6.26	1.24	0.42	0.37
Rendzina	A	9.30	0.33	0.09	3.52	2.85	3.49	0.13	0.25
	B	1.81	0.24		1.84	2.41	3.64	1.20	0.25
	C				3.46	2.83	3.53	1.40	0.25
	D				3.86	2.83	3.40	0.54	0.25

wenn der Gehalt des Bodens an Al_2O_3, Fe_2O_3, CaO und MgO ansteigt. Durch den Gehalt des Ammoniaks an kohlensaurem Ammon wird stets Kalk mitgeführt, so dass sich die richtigen Werte für die an der Fällung beteiligten Stoffe verschieben. Die Trennung mit Natriumacetat erlaubt allein zuverlässige Werte zu erhalten. Dass dem so ist, zeigen auf deutlichste die Gegenüberstellungen der Analysenbefunde in Tabelle 2. Die Acetatmethode liefert für Al_2O_3, CaO und MgO stets übereinstimmende Werte, während solches von der Ammoniakmethode nich behauptet werden kann. Im Gegenteil es schwanken hier die Werte sehr, und man erkennt die Schwankungen als Folge einer nicht durch Ammoniak herbeigeführten quantitativen Trennung.

APPENDIX 3

Report of the State Laboratory for Soil Science, Groningen, Holland

Dr. D. J. Hissink

Resultate Bodenprobe Hortobágy (Szik-Boden) in Prozenten auf Trockensubstanz

Gekocht wurde 10 Minuten ohne Rückflusskühler und dann entweder 60 Minuten oder 120 Minuten, also im Ganzen 70 Minuten oder 130 Minuten.

TABELLE 2—Vergleichende Resultate der vier Methoden, fur salzsäurelösliche Al_2O_3, CaO *und* MgO

Boden	HCl-lösl.	Trennung mit Ammoniak (*A*)				Trennung nach der Acetat Methode (*B*)				Trennung nach der Acetat Methode (*C*)				Trennung durch doppelte Fällung mit gereignigtem Ammoniak (*D*)			
Ungarn	Al_2O_3	4.25	4.50	4.70	4.30	3.27	3.26	3.29	3.30	3.73	3.70	3.70	3.72	3.72	3.56	3.94	3.80
	CaO	1.29	1.19	1.49	1.30	0.51	0.50	0.59	0.54	0.56	0.54	0.57	0.56	0.95	0.85	0.45	0.71
	MgO	0.08	0.07	0.05	0.08	0.62	0.60	0.70	0.65	0.93	0.90	0.95	0.92	0.50	0.51	0.54	0.45
Aegypten	Al_2O_3	15.21	14.84	14.64	14.99	8.11	8.10	8.06	8.08	10.87	10.84	10.89	10.81	15.59	15.84	15.68	15.25
	CaO	4.40	4.20	4.12	4.39	4.01	4.00	3.92	4.02	6.13	6.09	6.11	6.12	3.37	3.12	3.01	3.44
	MgO	0.10	0.09	0.09	0.11	2.37	2.36	2.37	2.37	2.34	2.30	2.34	2.35	0.60	0.59	0.71	0.61
Podsol	Al_2O_3	12.01	12.36	12.34	11.99	5.53	5.50	5.55	5.54	10.49	10.44	10.53	10.48	11.30	10.94	10.84	11.09
	CaO	0.42	0.62	0.28	0.55	1.92	1.94	1.90	1.89	1.00	0.98	1.04	1.01	1.35	1.11	1.30	1.21
	MgO	0.45	0.31	0.40	0.25	1.50	1.50	1.54	1.52	1.75	1.72	1.71	1.72	0.26	0.48	0.56	0.37
Rendzina	Al_2O_3	3.50	3.40	3.54	3.64	1.83	1.80	1.88	1.86	3.45	3.42	3.50	3.46	4.05	3.77	3.85	3.78
	CaO	3.39	3.62	3.38	3.58	3.63	3.65	3.63	3.63	3.59	3.51	3.54	3.50	3.29	3.49	3.41	3.40
	MgO	0.13	0.14	0.15	0.11	1.21	1.20	1.19	1.20	1.40	1.39	1.40	1.41	0.41	0.51	0.50	0.72

10 g. Boden wurden mit 100 cc. HCl oder mit 250 cc. HCl gekocht, also 1:10 oder 1:25.

Es sei noch hinzugefügt, dass geringe Mengen SiO_2 in der starken HCl in Lösung gehen (0.21 – 0.23 – 0.28 – 0.34) und ebenso geringe Mengen $F_2O_3 + Al_2O_3$ bei der Behandlung mit Lauge (0.14 – 0.08 – 0.14 ÷ 0.28).

Minuten	*Verhältniss*	*SiO_2*	*$F_2O_3 + Al_2O_3$*
70	1 : 10	10.61	8.41
130	1 : 10	11.49	9.01
70	1 : 25	10.43	8.48
130	1 : 25	11.47	9.19

Die Kochdauer hat etwas Einfluss gehabt; ob man aber statt 100 cc. HCl, 250 cc. HCl anwendet, ist egal.

APPENDIX 4

Report of the United States Department of Agriculture, Bureau of Soils, Washington, D. C.

Dr. P. L. Gile

Analyses of the standard samples which you transmitted were made by Messrs. R. S. Holmes and W. O. Robinson, in accordance with the method outlined in your circular. We did not receive the program of chemical work until quite recently and thus were not able to do as much work as we might otherwise have done. However, we trust that what we have done may be of some use to you.

In this laboratory we have been using the fusion method of analysis for many years. Some fifteen years ago the hydrochloric acid digestion method was widely used in this country. At that time a large amount of cooperative work was conducted for the purpose of standardizing the procedure with regard to strength of acid, time of digestion in order that concordant results might be obtained by different analysts. The procedure finally adopted was published in Bulletin 107 Revised, of the Bureau of Chemistry, United States Department of Agriculture.

Messrs. Holmes and Robinson have suggested that it might be well to substitute a constant boiling hydrochloric acid solution for the rather indefinite strength allowed in the procedure. If this were done, there would be less variation in the time required for the solution to reach a constant boiling point. They observed that it took from 10 to 15 minutes for the temperature to reach 108° heating with 25 per cent hydrochloric acid.

They also observed that in the case of the Badob soil more than 10 cc. of hydrochloric acid to each gram of soil should be used. The acid dissolves so much of this soil that 2 hours digestion carries the contents of the flask practically to dryness.

TABLE 1.—Analyses of the hydrochloric acid extracts of alkali, podsol and rendzina soils

Soil	Time of boiling hr.	Ratio of soil to acid	Wt. of sample	Analyst	Insoluble	SiO_2 in KOH	SiO_2 in HCl	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5
			g.										
	1	1:25	5	B	86.84	10.18	.18	.16	4.45	3.99	.39	.80	
	2	1:10	10	B	86.04	11.14	.10	.18	5.05	3.95	.37	.83	
Alkali	2	1:25	10	A	85.53	11.54							
	2	Do	5	A	85.51	11.38	.12	.20	5.17	4.02	.37	.86	.07
	2	Do	5	B	85.80		.18	.19	5.30	3.90	.36	.80	
	1	1:25	5	B	74.77	16.44	.20	.55	10.79	6.55	.37	1.63	
	1	1:10	10	B	73.86	19.60	.10	.56	11.92	6.40	.34	1.61	
Podzol	2	1:25	10	A	73.64	19.11							
	2	Do	5	A	74.20	19.47	.14	.57	11.82	6.51	.35	1.64	.11
	2	Do	5	B	73.37	18.11	.23	.56	11.78	6.55	.36	1.66	
	1	1:25	5	B	61.55	30.06	.22	.62	12.17	9.05		3.10	
Badob	1	1:10	10	B	62.26	30.58	.12	.67	11.94	8.85	4.40	3.10	
		1:25	10	A	59.92	30.76					4.38		
	2	Do	5	A	61.76	30.98	.23	.73	13.30	9.04	4.63	3.24	.24
		Do	5	B	61.00	30.99	.20	.66	13.10	9.10	4.42	3.27	
	1	1:25	5	B	80.94	9.12	.16	.20	3.32	2.95	3.54	1.44	
		1:10	10	B	80.66	9.99	.12	.22	4.05	3.00	3.45	1.43	
Rendzina		1:25	10	A	80.17	9.87							
	2	Do	5	A	80.23	10.20	.09	.18	4.14	2.91	3.48	1.49	.19
		Do	5	B	80.34	9.62	.25	.18	4.08	3.02	3.42	1.46	

APPENDIX 5

Bericht über die Vergleichsanalysen zur einheitlichen Bereitung der Bodenauszüge mit Salzsäure (Berichterstatter: Prof. Dr. A. Seiwerth, Zagreb, Kroatien *S H S*).

Im Bodenkundlichen Institut der land—und forst wirtschaftlichen Fakultät in Zagreb gelangten zu vergleichenden Analysen vier Bodenproben und zw.:

(1) ein Szik-Boden von Hortobágy—zugesandt vom Herrn Prof. Dr. A. A. J. de'Sigmond (Budapest);

(2) ein Badob—Boden aus Egypten—zugesandt vom Herrn Dr. A. F. Joseph (Karthoum);

(3) ein Rendzina—Boden von Cejc—zugesandt vom Herrn Prof. Dr. V. Novák (Brno);

(4) ein Podsol-Boden (Untergrund) von Zd'ar. zugesandt vom Herrn Prof. Dr. V. Novák (Brno).

Gang der Analyse

Zur Analyse wurden die lufttrockenen, durch ein 2 mm. Sieb durchgetriebenen und sorgfältig durchmischten Bodenproben genommen.

WASSERGEHALT DES LUFTTROCKENEN BODENS

Die Feuchtigkeit des lufttrockenen Bodens wurden an allen Proben, die an einem und demselben Tage für die Analyse abgewogen worden sind, durch Trocknen bis zur Gewichtskonstanz bei 105° C. bestimmt.

Der durchschnittliche aus drei übereinstimmenden parallelen Analysen berechnete Wassergehalt betrug für die einzelnen Bodenproben:

	prozent
1. Szik-Boden	3,29
2. Badob-Boden	7,74
3. Rendzina-Boden	3,37
4. Podzol-Boden	3,76

Der Bodenauszug.—Von jeder Bodenprobe wurde für das Boden-Säure-Verhältnis 1:10 und 1:25, sowie für deren Kochdauer von 1 und 2 Stunden, je swei sauere (Salzsäure) bzw. zwei alkalische (Kalilauge) Auszüge bereitet, und in jedem Auszug wurde dann die gelöste Kieselsäure SiO_2 sowie die Sesquioxide X_2O_3 quantitativ bestimmt.

Der sauere Bodenauszug.—Zur Bereitung der Bodenauszüge mit Salzsäure wurden stets 10 g. der lufttrockenen Bodenprobe und 100 bezw. 250 cc. Salzsäure von 28 Gewichtsprozent genommen.

Die Extraction wurde in Erlenmeyerkolben aus Jenaer—Glas vom Inhalt 500 bzw. 750 cc. ausgeführt.

Das Boden-Salzsäuregemisch wurde vorerst im offenen Glaskolben auf offener Gasflamme eines Bunsenbrenners erhitzt bis die maximale Kochtemperatur der Lösung von 109–110° C. erreicht wurde, und sodann wurde nach dem Ansätzen eines Rückflusskühlers, dessen Kühlmantel eine Länge von 40 cm. hatte, auf den Kolben noch weiter genau eine bzw. zwei Stunden gekocht. Nach der beendeten Kochzeit wurde das Gemisch weiter nach der Zugesandten Beschreibung (Rundschreiben der II. Intern. Kommission in den Mitteilungen der Int. Bodenkundlichen Gesellschaft, Bd. I. Nr. 2, 1925) behandelt.

Die filtrierte salzsauere Lösung wurde sodann in einer Porzellanschale auf dem Wasserbade eingeengt und zur Verbrennung der organischen Substanz und Trennung der Kieselsäure weiter nach Gedroiz[1] behandelt.

Die abgeschiedene Kieselsäure wurde abfiltriert, ausgewaschen, getrocknet, geglüht, gewogen, und auf Reinheit geprüft.[2]

Die von der Kieselsäure abfiltrierte salzsauere Lösung wurde in einem Messkolben zur Marke aufgefüllt, durchgemischt und zur Ammoniakfällung verwendet.

Ein aliquoter Teil, entsprechend 1 g. Boden, die ser salzsaueren Lösung wurde mit einem Überschuss von Ammonchlorid versetzt, erhitzt und mit einem geringen Überschuss von Ammoniak gefällt.

Der durch Dekantieren und Auswaschen auf dem Filter mit heissem Wasser, dem etwas Ammoniak und Ammonnitrat zugesetzt worden ist, gereinigte Niederschlag, wurde verbrannt und nach dem Erkalten gewogen.

Der alkalische Bodenauszug.—Der vollkommen neutrale Bodenrückstand nach dem salzsäurem Aussug wurde im Wasserbade getrocknet, das Filter verascht und die Asche zum trockenen Rückstand im Kolben gebracht. Zur Lösung der abgeschiedenen Kieselsäure wurde der Trockenrest im Kolben mit 200 cc. Kalilauge vom sp. Gew. 1,04 übergossen und auf einem Asbestdrahtnetze mit Gasflamme solange erwärmt bis die Flüssigkeit die Temperatur 55° C. erreichte. Die dazu nötige Zeit überschritt nicht 5 Minuten. Sobald die Temperatur von 55 °C. erreicht war, wurde der Kolben sofort in ein auf 55° C. vorerwärmstes Wasserbad 5 cm. tief hineingestellt und im Wasserbade 5 Minuten unter ständigem Umrühren belassen. Nach Verlauf von diesen 5 Minuten wurde sofort kaltes Wasser hinzugegossen und nach der vorerwähnten Beschreibung dekantiert.

Sodann wurde mit der klaren alkalischen Lösung, die stark mit Salzsäure angesäuert worden ist, weiter wie mit dem salzsaueren Auszug verfahren.

Um die Ungleicheiten in der Ausführung der Analysen tunlichst aus-

[1] Gedroiz: *Arbeits-Methoden d. chem. Bodenanalyse*, Földt. Közl XLII. Budapest 1912.

[2] Treadwell: *Kurzes Lehrbuch d. anal. Chemie*, II., 9. 1921.

TABELLE 1.—*Resultate der Analyse*

Bodenprobe	Extrakt.	Boden : Säure = 1 : 10								Boden : Säure = 1 : 25								Humus[a]	$CaCO_3$[a]
		Kochsdauer 1 Stunde				Kochsdauer 2 Stunden				Kochsdauer 1 Stunde				Kochsdauer 2 Stunden					
		SiO_2		X_2O_3		SiO_2		X_2O_3		SiO_2		X_2O_3		SiO_2		X_2O_3			
		%	Mittel %	%	Mittel %	%	Mittel %	%	Mittel %	%	Mittel %	%	Mittel %	%	Mittel %	%	Mittel %		
I Szik-Boden, Ungarn	HCl	0.16 0.10	0.13	8.22 8.87	8.55	0.22 0.11	0.17	9.26 9.20	9.23	0.19 0.17	0.18	9.15 8.94	9.05	0.15 0.22	0.19	9.89 9.62	9.76	1.47	
	KOH	9.41 9.58	9.50	0.14 0.13	0.14	10.18 10.36	10.27	0.11 0.10	0.11	10.22 10.20	10.21	n.	b.	10.89 10.46	10.67	0.14 0.12	0.13		
II Badob, Egypten	HCl	0.28 0.30	0.29	21.77 22.35	22.06	0.30 0.28	0.29	23.25 23.02	23.14	0.25 0.29	0.27	22.85 23.05	22.95	0.39 0.40	0.40	23.86 23.68	23.77	0.97	5.90
	KOH	31.03 30.25	30.64	0.68 0.31	0.49	30.99 30.57	30.78	0.43 0.31	0.37	30.94 30.55	30.75	0.53 0.25	0.39	30.52 30.37	30.45	0.46 0.21	0.34		
III Rendzina, Böhmen	HCl	0.10 0.10	0.10	6.67 6.44	6.56	0.15 0.13	0.14	7.62 7.45	7.54	0.23 0.25	0.24	7.23 7.30	7.27	0.26 0.22	0.24	7.75 8.00	7.88	4.62	5.70
	KOH	8.74 8.40	8.57	0.11 0.10	0.11	9.90 9.34	9.67	0.12 0.10	0.11	9.26 8.84	9.05	0.10 0.10	0.10	9.59 9.77	9.68	0.18 0.14	0.16		
IV Podsol, Böhmen	HCl	0.23 0.25	0.24	17.96 18.06	18.02	0.26 0.27	0.27	18.70 18.41	18.60	0.24 0.21	0.23	18.81 18.50	18.66	0.25 0.27	0.26	18.86 18.70	18.78	0.39	
	KOH	17.02 17.76	17.39	0.07 0.10	0.09	18.00 18.30	18.15	0.10 0.14	0.12	18.91 18.97	18.94	0.18 0.20	0.19	19.86 19.63	19.75	0.32 0.22	0.27		

[a] nach Angaben der pedologischen Anstalt in Brno.

zuschalten, wurden alle Auszüge (Bereitung und Analyse) jeder Bodenart stets von einem Analytiker besorgt und die Ergebnisse der Parallelanalysen und deren arithmetischen Mittel sind, umgerechnet aus Trokensubstanz (105° C.) in der Tabelle 1 zusammengestellt.

Ausserdem liess ich um festzustellen, wie weit sich die Ergebnisse verschiedener Analytiker decken, eine jede Bodenart nochmals von einem zweiten Analytiker unter möglichst gleichen Bedingungen untersuchen. Diese Untersuchung erstreckt te sich vorläufig nur auf das Boden-Säure-Verhältnis 1:25 für eine einstündige Kochdauer, und die Ergebnisse jedes Analytikers im Einzelnen und im Durchschnitt, sowie die Differenz der erhaltenen Mittelwerte sind in Tabelle II. wiedergegeben.

TABELLE 2.—Ergebnisse der zwei Analytiker

Bodenprobe	Extrakt.	Analytiker 1				Analytiker 2				Differenz	
		SiO_2		X_2O_3		SiO_2		X_2O_3		SiO_2	X_2O_3
		%	Mittel %	%	Mittel %	%	Mittel %	%	Mittel %	%	%
I	HCl	0.19 0.17	0.18	9.15 8.94	9.05	0.14 0.14	0.14	8.92 8.79	8.86	0.04	0.19
	KOH	10.22 10.20	10.21	n.	b.	11.16 10.72	10.94	n.	b.	0.73	
II	HCl	0.25 0.29	0.27	22.85 23.05	22.95	0.23 0.25	0.24	22.60 22.42	22.51	0.03	0.44
	KOH	30.94 30.55	30.75	0.53 0.25	0.39	29.99 29.60	29.79	n.	b.	0.96	
III	HCl	0.23 0.25	0.24	7.23 7.30	7.27	0.20 0.21	0.21	7.05 7.11	7.08	0.03	0.19
	KOH	9.26 8.84	9.05	0.10 0.10	0.10	8.30 8.74	8.52	n.	b.	0.53	
IV	HCl	0.24 0.21	0.23	18.81 18.50	18.66	0.20 0.19	0.20	18.39 18.21	18.30	0.03	0.36
	KOH	18.91 18.97	18.94	0.18 0.20	0.19	18.72 18.39	18.56	n.	b.	0.38	

Schlussfolgerungen und Schlussbemerkungen

(1) Die bei einer und derselben Bodenart gewonnenen Ergebnisse der Parallelanalysen eines Analytikers (Tabelle 1) sowie auch zweier Analytiker stimmen praktisch zu genüge überein.

(2) Die Ergebnisse beim Boden-Säure-Verhältnis 1:25 sind im allgemeinen höher als die beim Boden-Säure-Verhältnis 1 : 10 und entsprechender Kochdauer.

(3) Die Ergebnisse der zweistündigen Kochdauer sind höher als die Ergebnisse der einstündigen Kochdauer bei ein und demselben Boden-Säure-Verhältnis.

(4) Die höchsten Ergebnisse wurden im Allgemeinen beim Boden-Säure-Verhältnis 1:25 und zweistündiger Kochdauer erzielt.

(5) Die Ergebnisse beim Boden-Säure-Verhältnis 1:25 und zweistündiger Kochdauer nähern sich mehr oder weinger den beim Boden-Säure-Verhältnis 1:10 und zweistündiger Kochdauer sowie den beim Boden-Säure-Verhältnis 1:25 und einstündiger Kochdauer erhaltenen Werten.

(6) Die durch zweistündige Kochen beim Boden-Säure-Verhältnis 1:10 und einstündiges Kochen beim Boden-Säure-Verhältnis 1:25 erhaltenen Werte stimmen praktisch gut überein.

(7) Mit Rücksicht des zu leichten Verkochens und Verspritzens beim Boden-Säure-Verhältnis 1:10 gebe ich den Vorzug dem Verhältnis 1:25 zwischen Boden und Säure.

(8) Betrachtet man das Verfahren von van Bemmelen-Hissink, von der packtischen Seite aus, so ist entschieden ein Nachteil dieses Verfahrens das Kochen im offenen Glaskolben, da der Analytiker trotz der Kurzfristigkeit dieses Vorganges empfindlich durch Chlorwasserstaff-Gas belästigt wird und in Laboratorien die nicht mit tadellosen Abzugsschränken oder Säurekammern ausgestattet sind selbst auch die Laboratiriumseinrichtung zu sehr leidet und schliesslich da bei vielen Analysen solcher Art auch der materielle Verlust, der durch das Abkochen des Chlorwasserstoffs entsteht nich ganz bedeutungslos ist.

Dieser Umstände wegen sind wir bestrebt ein einfacheres Verfahren zur Bereitung des Salzsäurenbodenauszuges, welches übereinstimmende Ergebnisse mit dem Vorerwähnten liefert, festzustellen.

(9) Was das Kochen betrifft glaube ich, dass ein einstündiges Kochen ausreichend ist.

(10) Sollte das Verfahren von van Bemmelen-Hissink als Konventionelle Methode zur Bereitung des Bodensalzsäureauszuges in Vorschlag gebracht werden, dann müsste durch exacte Fassung der Arbeitsvorschrift auf Erziehlung möglichst gleichmässiger Analyseergebnisse hingearbeitet werden.

In dieser Vorschrift sollte auch folgendes angegeben werden:

(a) ob der Boden mit Salzsäure in einem ganz offenen oder in einem mit einem Trichter versehenen Glaskolben auf der offenen Gasflamme erhitzt werden soll;

(b) ob der Siedepunkt von 110° C. durch Messung in der Lösung oder im Dampfe zu bestimmen ist;

(c) die Wassermenge zum verdünnen und die Zeit zum Absitzen-lassen der unlöslichen Bestandteile nach dem Kochen unter dem Rückflusskühler.

Um hier einheitlich zu verfahren, meine ich, würde es vielleicht vorteilhaft sein, mit doppelter Menge Wasser zu verdünnen und zum Absitzen der festen Bestandteile vom Nachmittag bis zum Morgen ruhig stehen zu lassen;

(d) Die Bedingungen unter welchen die Temperatur von 55° C. des Bodenrestes Kalilauge vor dem Schütteln zu erreichen ist, ob durch erwärmen des Gemenges auf einem Asbestdrahtnetze mit Gasflamme oder einem anderen Verfahren.

Nach bis jetzt gesammelten Erfahrungen scheint mir das folgende Verfahren zur Bereitung des alkalischen Bodenauszuges die besten Übereinstimmungen der Parallelanalysen zu geben:

Der Erlenmayerkolben sammt dem getrockneten Bodenrückstand nach dem salzsaueren Ausszug und der Asche des Filters wird um die Temperatur von 55° C. anzunehmen auf eine halbe Stunde in einen Trockenschrank der auf 55° C. erwärmt worden ist, hineingestellt. Nach dieser halben Stunde werden zum Rückstand in der Kolben 200 cc. auf 55° C. erwärmte Kalilauge von sp. Gew. 1,04 gegossen und sodann wird der Kolben sofart in ein Wasser- (Luft-) bad, das auf 55° C. vorerwärmt worden ist, hineingestellt und in demselben 5 Minuten unter Umrühren (Schütteln) belassen.

III. Nutritive Materials in Soils.—Dr. A. A. J. de'Sigmond, with Dr. A. Zohls, and Dr. E. Becker, Hungary, introduced a discussion of the chemical determination of the nutritive materials in soils.

DISCUSSION OF THE CHEMICAL DETERMINATION OF THE NUTRITIVE MATERIALS IN SOILS

Drs. A. A. J. de'Sigmond, A. Zohls and E. Becker

Introduction

The aim of this paper is not to discuss the practical use and availability of the chemical determination of the nutritive materials in soils, but to review the literature concerning the different analytical methods used and proposed for this purpose in order to have a systematic guide to discuss voluminous literature on this subject. We are aware, that it is hardly possible to cover every method, but we will mention only those, which are familiar to us, and further discussion of the subject will comprise the remainder of our report. As regards the principle of systematizing the material, we propose to discuss first; the chief nutritive materials, then that part which is easier soluble or decomposable than the total.

I. Phosphoric-acid Determination in Soil

A. TOTAL PHOSPHORIC ACID

1. Complete decomposition by:

(a) Fusing with Na_2CO_3 as in mineral analysis, in the case where phosphoric acid only is wanted, or

(b) With HF, especially when total potassium is wanted (3).

2. Decomposition with aqua regia, as the strongest acid (2, 7).

3. Decomposition with concentrated H_2SO_4 and concentrated HNO_3 similar to the treatment of Thomas slag. The concentrated sulfuric acid decomposes chiefly the mineral part, the nitric acid the organic compounds of the soil (7). Mention should be made of the method of Hissink (5).

4. Treatment with concentrated HNO_3.

(a) Hilgard's Method (16). The principle consists in first igniting the soil sample, in order to decompose the organic matter and the carbonates, and then to dissolve the phosphoric acid decomposed by an excess of concentrated nitric acid.

(b) Taranow's Method (4). The principle consists in extracting quickly and completely the total phosphoric acid, by treating the soil with a little concentrated nitric acid and heating on an asbestos wire gauze; the nitric acid being repeatedly replaced and evaporated. At the end all phosphoric acid will be dissolved by pure water.

5. Treatment with concentrated HCl according to Wolff. Perhaps the most widely known method for total phosphoric acid (15). Treatment with 10 per cent HCl.

6. It should be mentioned here, that many investigators use 10 per cent HCl for the determination of total phosphoric acid in soils (7). It is evident though, that this will seldom give the total amount of phosphoric acid in soils.

B. PHOSPHORIC ACID SOLUBLE IN WEAK ACID

1. Phosphoric acid dissolved by dilute HNO_3 according to de'Sigmond (11, 12, 13). The principle of the method is to determine first, how much acid is required for 25 g. of soil to obtain a final acidity of about 200 to 1000 mg. N_2O_3 per liter of solution. This is called the "basicity" of the soil. The limits of the soluble phosphoric acid vary according to the basicity of the soil. The author has used this method with success to detect whether the soil is lacking in available phosphoric acid or not. It is more a qualitative test as regards the need of phosphoric acid, rather than a quantitative one. It is based on a natural limit, characteristic for most soils, as regards the decomposing power of very dilute nitric acid on natural soil phosphates, but has also some plant physiological basis, though it does not determine the properly available phosphoric acid. Being supported by numerous fertilizer experiments in pot cultures and in the field it may serve as an indication of the deficiency or richness of available phosphoric acid. This method eliminates also the interfering action of the natural buffer action of the soil against weak acids. It still represents a quantitative chemical basis showing whether the soil is poor or rich in easily soluble phosphates. We use it with success in combination with the azotobacter test and the Neubauer (10) physiological experiment.

2. The relative solubility of the phosphoric acid of the soil according to Lemmermann. The principle of this method is based upon the determination of total phosphoric acid and that of phosphoric acid soluble in 1 per cent citric acid by the method of Perju. The per cent of the latter in the total phosphoric acid is called by Lemmermann (8) the measure of the relative solubility, which has proved reliable in detecting the need or abundance of available phosphoric acid in soils. It must be called to the attention, however, that the presence of citric acid complicates to some extent the precipitation of phosphoric acid, and if the soil is rich in calcium carbonate the virtual acidity of the solvent can be changed considerably. That is the reason why in soils deficient in calcium carbonate as a rule the 1 per cent citric acid will dissolve more phosphoric acid from the soil than the above mentioned nitric acid, whereas in soils rich in calcium carbonate we often find the reverse. This latter difficulty can be eliminated by the method of Hissink (5). Mention should be made of the method of Dyer (1) and H. W. Wiley (14) and the method of Konig and Hasenbaumer (6).

At this point we might mention that at the Hungarian Royal Institute of Chemistry we have evidence, to the effect that the presence of titanium is very often responsible for analytical discrepancies especially in the case of total phosphoric acid. According to the experiences of J. Semián, former soil expert at the above Institute, it happened, especially in sandy soils, that about 50 per cent of the total phosphoric acid was lost in the analysis, precipitating partly with the silicic acid and partly after dissolving the phosphomolybdate precipitate, as an insoluble turbidity. If we want to get reliable results, we should always test first for titanic acid in the soil extract and, if present, eliminate its disturbing effect. It seems, that especially in the concentrated hydrochloric acid extract this analytical interference is not very rare.

II. Potassium Determination in Soil

For total potassium we can use the same methods as under phosphoric acid except the decomposition with Na_2CO_3; but perhaps the most reliable method seems to be the decomposition of the soil with HF.

As regards the relative solubility, we have the method of Lemmermann (8) but instead of citric acid he suggested 10 per cent HCl. The per cent of potassium dissolved by 10 per cent HCl in the total as 100, will give a good indication of the need of or abundance of available potassium and combined with the physiological method of Neubauer may be used as a basis for fertilizer experiments. The azotobacter test for potassium seems to be, according to our experiences, not as reliable and sensitive as for phosphoric acid. We have some evidence from which we might suppose, that the treatment with dilute nitric acid, according to de'Sigmond, will give similarly good results, as Lemmermann also has shown. This makes it necessary to study this question further.

III. Nitrogen Determination in Soil

In this respect the available laboratory chemical tests are not very instructive. The total nitrogen (Kjeldahl's method) modified by Mitscherlich (9) as well as the humus nitrogen (Hilgard's method) may be useful if we already have practical evidences, of the need of nitrogen fertilizers. This supplemented by bacteriological experiments as regards ammonification and nitrification can serve as a basis for practical fertilizer experiments.

As regards the testing for soil acidity and lime requirement the transactions of the Second Commission of the Society of Soil Science (Vols. A and B) give full information about the present status of this question.

Experimental Data

In order to give some experimental material for the discussion of the above points, we may illustrate them by some experimental data, which were collected from the analytical data of the Hungarian Royal Institute of Chemistry, Budapest, Hungary.

1. We have compared most of the above mentioned methods for total phosphoric acid on the yellow clay soils of Kapurvár, containing no calcium carbonate and having a pH in a water suspension of 6.14 in the surface soil and 6.68 in the subsoil. Both soils possessed considerable latent acidity and degree of unsaturation, the respective analytical data, however, are not needed for the question to be treated here. Table 1 will show the concordance of the results, obtained by the different methods.

TABLE 1.—Total phosphoric acid in dried soil

Method	Surface soil	Subsoil
	per cent	per cent
1. Complete decomposition by fusing with Na_2CO_3	0.298 P_2O_5	0.274 P_2O_5
2. Treated with aqua regia	0.287 P_2O_5	0.266 P_2O_5
3. Treated with concentrated H_2SO_4 and concentrated HNO_3	0.287 P_2O_5	0.266 P_2O_5

In this case we have but a very slight excess with the first method, probably because the soil was deficient in organic matter, calcium carbonate and titanium.

But in another case, where the soil was rich in calcium carbonate (about 17 to 60 per cent) and the organic matter, as in a peaty soil, was very resistant to the decomposing action of the acid solution we could not get any reliable results. In similar cases we have no better method for total phosphoric acid, than the complete decomposition by fusing with sodium carbonate. In soils in which the calcium carbonate is not in abundance or completely deficient, and the oxidation of the organic matter is easily

accomplished with concentrated nitric acid we have found most convenient the method of Hilgard with concentrated nitric acid after ignition, or the method of treating the soil with concentrated sulfuric acid and concentrated nitric acid and using the method of Lorenz for the direct determination of phosphoric acid as phosphomolybdate precipitate.

2. As regards the relation of phosphoric acid soluble in a weak acid to the azotobacter test and to the Neubauer experiments, we might quote the analytical results and field experiments of the peaty soil at Palavica, rich in calcium carbonate. In the field experiments carried on by Prof. Alexander Faber of the Agricultural College at Keszthely, Hungary, the soil proved deficient in available phosphoric acid with four different cultures. The most sensitive was the hemp and beet rather than the potato and the oats mixed with vetches. Table 2 will give the respective yields. Further details will be published by Prof. Faber.

TABLE 2.—Yield per Hungarian acre in kg.

	Hemp	Beets	Potatoes	Hay of oats and vetches
Check plot	Practically nothing	Practically nothing	2293	412 626
Plot with 200 kg. superphosphate of 18 per cent water-soluble P_2O_5	5013	13.760	8133	946

It is evident from these figures, that the soil was very deficient in available phosphoric acid. The respective data of the laboratory tests are collected in Table 3.

We can see in this instance, that the laboratory tests harmonize in proving both soil samples, surface and subsoil, to be poor in easily soluble available phosphoric acid, this result also being affirmed by the field experiments in Table 2.

The Hungarian Foundation for National History is materially supporting the study of this question under the leadership of de'Sigmond, and cooperative work has already been started between the Soil Laboratory, of the Hungarian Royal Joseph-University of Technical Sciences and the Hungarian Royal State Institute of Chemistry in Budapest, as well as the Hungarian Royal State Experiment Station of Plant Industry in Magyaróvár, and several large private dominions and estates to study the practical value of these different laboratory methods. It would be of general interest to inaugurate international cooperation to study comparatively these methods in the laboratory and controlling the results by field experiments. If the various countries, which are interested in this subject would carry out a number of laboratory tests combined with field experi-

TABLE 3.—Comparison of phosphoric methods

Method[a]	Surface soil 0–40 cm.	Subsoil 40–100 cm.
Per cent total P_2O_5 determined according to A.1a.	0.036	0.046
Per cent P_2O_5 soluble in 1 per cent acid	0.0004	0.0011
Per cent relative solubility according to Lemmermann	1.11	2.60
Per cent P_2O_5 soluble in weak HNO_3 according to de'Sigmond	0.025	0.026
Basicity of the soil according to de'Sigmond	5680	19,860

[a] Tests:

Azotobacter test:

1. Check culture	No development	No development
2. With $CaCO_3$	Do Do	Do Do
3. With 2 cc. phosph. sol.	+++	++++
4. As 3, with $CaCO_3$	++++	++++

Result, very strong reaction for phosphoric acid, none for $CaCO_3$

Neubauer test:

	mg. P_2O_5	mg. P_2O_5	
a.	1.84	3.50	Harvested on the 14th day
b.	1.42	3.18	
c.	1.69	3.67	
Average	1.65	3.45	

ments, we would have a basis for building up uniform methods and general opinion about the practical use of the laboratory methods.

Recommendations

We take pleasure in recommending as a basis of discussion the following plan of cooperative experiments:

The members of the Second, Third and Fourth Commission of the different countries should be invited to do cooperative work according to the following plan:

In the various countries a large number of soil samples should be tested according to the following plan:

I. 1. Treatment with weak nitric acid according to de'Sigmond's method.

2. Determining the relative solubility according to Lemmermann.

3. Azotobacter test according to the plan of Table 3.

4. Neubauer experiments.

5. Pot experiments according to the plan of Mitscherlich.

6. Field experiments according to the results of the laboratory tests 1 to 4.

II. 1. Determination of total potassium by treatment of the soil with hydrofluoric acid.

2. Relative solubility of potassium by treating the soil with 10 per cent hydrochloric acid according to Lemmermann.

3. The same by treating the soil with weak nitric acid according to the method of de'Sigmond.

4. Neubauer experiments.

5. Azotobacter test for potassium.

6. Pot experiments according to Mitscherlich.

7. Field experiments according to the results of the laboratory tests 1 to 5.

III. 1. Total nitrogen according to the Kjeldahl method.

2. Humus nitrogen according to Hilgard.

3. Nitrification test.

4. Pot experiments according to Mitscherlich.

5. Field experiments according to the laboratory tests 1 to 3.

IV. Attention should be called to the experiment stations of the different countries, that in the case of fertilizer experiments in pot cultures or in fields, the respective laboratory tests should not be neglected, in order to get as large material as possible for the above cooperative investigations.

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Dr. N. M. Comber, England, presented the following report of the Washington sessions of the joint meetings of Commissions II and IV, which occurred on Tuesday, June 14, and Wednesday, June 15, at 2:15 P.M. both days. On Saturday, June 18, and Monday, June 20, these commissions were joined by Commission I in sessions at 10 A.M., while Commissions II and IV met together on the afternoon of the latter date, at 2:30 P.M.

FIRST INTERNATIONAL SOCIETY OF SOIL SCIENCE

Washington Meetings, June, 1927

Proceedings of the Second Commission

JOINT MEETING OF COMMISSIONS II AND IV

Tuesday, 14th June, 2:15 P.M.

Chairman, Prof. M. M. McCool

Secretaries, Dr. M. Trénel, Dr. R. Görz, Prof. N. M. Comber

Prof. de'Sigmond made fitting reference to the deaths of Dr. Christensen and Dr. Vesterberg who had rendered valuable services on the Committee of the Commission.

The following papers relating to

Plant Nutrients in Soils

were read:

Joffe, J. S., and McLean, H. C.
 Availability of replaceable cations
 Probable influence of anions on aluminium solubility in soils

'Sigmond, A. A. J. de, Zohls, A., and Becker, E.
 Discussion of the chemical determination of the nutritive materials in soils

Parker, F. W.
 Recent studies on the phosphate content of the soil solution and its relation to the phosphorus nutrition of the plant

McHargue, J. S.
 The significance of small amounts of inorganic elements in plants

Skinner, J. J.
 The influence of nitrogen, phosphate and potash on the growth, quality and maturity of cotton

Alway, F. J.
 Detection of sulfur-deficiency of soils by means of plants

Wednesday, 15th June, 2:15 P.M.

Chairman, Prof. A. A. J. de'Sigmond

Secretary, Prof. N. M. Comber

The following papers on

THE ACID EXTRACTION OF SOILS FOR ANALYSIS

were read:

'Sigmond, A. A. J. de

Conclusions concerning the uniform preparation of soil extracts with hydrochloric acid

Ganssen, R.

Gesetz mässigkeiten im Böden

DISCUSSION

The two methods advocated by Prof. de'Sigmond and by Prof. Ganssen were each upheld by their respective supporters.

Prof. Hendrick pointed out that the subject did not merit prolonged and serious discussion since the extraction of soils with concentrated acid was now a process of minor importance in soil analysis, and it was largely a matter of indifference which procedure was adopted.

Prof. Comber suggested that in fixing the amount of acid to be used allowance should be made for the calcium carbonate present in the soil.

Dr. Reifenberg pointed out that one chief value of acid extraction is the discrimination between the colloidal and the non-colloidal constituents of the soil. Any one fixed concentration of acid will take more or less of the unweathered part of a soil according to the soil type, and the conditions, such as the strength of the acid, fixed by the examination of one soil may not be valid for another.

On the suggestion of Mr. W. H. Shaw, it was agreed that the methods advocated by Prof. de'Sigmond and Prof. Ganssen should both be tentatively acknowledged until definite evidence in favor of the superiority of one of them is forthcoming (see page 234 for Committee appointed to deal with this).

The following

MISCELLANEOUS PAPERS

were read:

Prianischinikow, D. N., Golubew, B. A.

The decomposition of carbonates and phosphates by the soil acidoids

Dufrenoy, G.

The reaction of the waters of some thermal springs

Bradfield, R.

The use of electrodialysis in physico-chemical investigations of soils

Variables involved in the flocculation of colloidal clay

MacIntire, W. H., and Shaw, W. M.

The absorption of $Ca(OH)_2-CaSO_4$ by soil as a possible index to colloidal alumina and silica

Görz, G.

The use of the relation between the relative conductivity of electrolytes and the ionic mobility in the soil solution studies, and the possibility of an electric determination of the soil nutrients

Saidel, T., and Cernescu, N.

New contributions to our knowledge of soil solution

Results of determination of the reaction of Rumanian soil types

Salminen, A.

A procedure for determining soluble electrolytes in soils

Rost, C. O.

Electrodialysis in studies of soil deficiencies

Bizzell, J. A., and Lyon, T. L.

Composition of drainage waters from lysimeters at Cornell University

Burd, J. S.

An important aspect of soil solution research

Hendrick, J., and Welsh, H. D.

The substances removed by the drainage from a Scottish soil

Spurway, C. H.

Microchemical soil tests

Prianischnikow, D. N., and Drujinin, D. W.

The action of chalk and phosphate on the podsol soils

Benade, W.

Relations between the relative conductivity of electrolytes and the ionic mobility

Pierce, W. H., and Parker, F. W.

The use of collodion sacks in soil investigations

Reifenberg, A.

The function of silicic acid as a protective colloid in the formation of Mediterranean red soils

McCool, M. M.

The rôle of colloids in soil productivity

Ganssen, R.
 Natural laws in soil systems

Görz, G., and Benade, W.
 Regeneration power of soils and its determination

Ganssen, R.
 The regenerative power of the soil and its determination

Wheeting, L. C.
 Some relationships between soil colloids and water

Discussion

Dr. Magistad said that he had found in work on artificial zeolites at Arizona that whenever hydrogen zeolite is formed from basic zeolite, a portion of the hydrogen zeolite is always broken down. This is also true of the soil zeolites. In Dr. Bradfield's method of electrodialysis a hydrogen zeolite is formed and is later titrated with an appropriate base to neutrality. If a breakdown of the hydrogen zeolite occurs, the titration cannot be quantitative. Dr. Bradfield replied that such a breakdown of hydrogen absorption compounds takes place only when the pH becomes very low, and that in electrodialysis the pH of the solution in the chamber containing the clay never becomes low enough to cause such a breakdown.

Dr. Reifenberg asked if electrodialysis would not be vitiated by the presence of calcium carbonate such as occurs in the Palestine soils.

Dr. Bradfield replied that as electrodialysis proceeded and the hydrogen complex was formed it would automatically decompose the calcium carbonate, the calcium of which would ultimately find its way to the outer chamber.

Dr. Crowther asked if Dr. Bradfield had ever found aluminium appearing in the outer chamber.

Dr. Bradfield replied that small amounts of aluminium are sometimes present especially where the soluble salts of the soil have not been previously removed.

JOINT MEETING OF COMMISSIONS I, II AND IV

Saturday, 18th June, 10 A.M.

Chairman, Prof. A. A. J. de'Sigmond

Secretaries, Dr. M. Trénel and Prof. N. M. Comber

Dr. Lemmermann presented a report of the Proceedings of the Second Commission, which was held at Groningen, in April, 1926, dealing with the physiological significance and theories of soil acidity. This was followed by a similar report by Dr. Comber, dealing with the estimation of soil acidity.

THE DETERMINATION OF SOIL ACIDITY

Report of the Proceedings of the Second Commission, Groningen, 1926

DR. N. M. COMBER, Associate Referee

In presenting the report of the meeting of the Second Commission held at Groningen in April last year to discuss soil acidity and base exchange, it has been found convenient to segregate three aspects of the matter, namely the theories and physiological significance of soil acidity, with which Prof. Lemmermann has dealt, base exchange with which Dr. Hissink will deal, and the estimation of soil acidity upon which I will now report briefly. There can however be no real segregation of these aspects as they are all so interdependent. The dependence of methods of determining soil acidity upon our theoretical conceptions and upon the physiological significance of soil acidity and the dependence of these upon base exchange phenomena are very obvious.

The members of the Second Commission who met at Groningen had in mind the ultimate dependence of the methods used upon theoretical views, and the Commission does not suggest that any methods shall be adopted internationally with any idea of their being other than tentative methods. International adoption of tentative methods must however have its value. It will lead to greater facility in comprehending the results obtained in other laboratories and in other countries. It will also expedite the improvement of technique and it will inevitably assist the progress of our theoretical understanding.

The problem of estimating soil acidity is three-fold. There is first, the preparation of the sample; second, the preparation of the suspension of that sample; and third, the determination of the pH of that suspension.

THE PREPARATION OF THE SAMPLE

The recommendations of the Commission are set out in Volume B of the Transactions, page 80. Three points arise in connection with the preparation of the sample. There is first, the question of the effect of air-drying on the soil reaction; second, the effect of storing an air-dried sample; and third, the effect of fineness of division.

So far as air-drying is concerned, the results obtained by Biilmann and Jensen (Vol. B, p. 260) show that there is in general a very slight increase in acidity consequent upon air-drying, but the difference is very small and in most cases is probably within the limits of experimental error. The conditions of air-drying are known to affect appreciably the pH value ultimately obtained. The higher the temperature at which the soil is dried, the greater is the acidity.

The drying-out of a soil in the laboratory and the drying-out of the same soil in the field may affect the pH value differently. It is very

clear, of course, that the conditions are different. In particular the soil drying in the field will receive water from below which on evaporation from the surface will leave previously dissolved material in the surface soil.

The Committee recommend in tentative proposals that the determination of the pH should be made as soon as possible after air-drying. The effect of storing an air-dried sample has yet to be further investigated, but it is clear that it may have some effect. The results obtained by Terlikowski (Vol. B, p. 152) show that the storing of a sample over a period of 56 days brings about very little differences in the pH value when the soil is suspended in a small quantity of water. When, however, the ratio of water to soil is high, the difference in the pH of the nearly dry sample and the stored sample may be as great as 0.25. Some of the most striking figures yet brought forward in this connection are those quoted by Mitscherlich (Vol. B, p. 52). The storing of a soil from May until October causes the pH of one soil to alter from 6.5 to 5.0. In another case the change was from 5.7 to 4.5. In all five cases quoted the change was considerable. Pending further investigation it is recommended that the nearly dry sample shall be used.

Coming now to the question of fineness of division, opinions vary but it is generally agreed that a more systematic observation of the effect of this upon pH is required. In our experience at Leeds we are inclined to attach considerable importance to this. Most of the English soils appear to be constituted in such a way that the soil crumb may be relatively highly saturated with calcium and *as a crumb* suspended in water may give a reaction very much less acid than when the crumb is broken up and the inner surfaces of particles much less highly saturated with calcium are exposed.

There is no doubt that different types of soil vary considerably in the way in which air-drying, storing, and fineness of division affect their reaction. The Commission has urged in its Report that further investigations are desirable. Meanwhile the recommendations that the soil be air-dried and examined as soon as possible after taking the sample seem reasonable.

The Preparation of the Suspension

The first point that arises in connection with the preparation of the suspension is the relative merits of water suspensions and salt suspensions. At first sight it would appear wholly reasonable to use water as approximating more nearly to natural conditions, and most investigators probably do use water. On the other hand, some of the German workers use a N KCl solution, and for this they have apparently much justification as shown by the figures quoted by Lemmermann (Vol. A, p. 15). Here it is seen that the pH value of good and bad parts of a field are identical when the soil is suspended in water but are considerably different (the bad

parts being very acid) when KCl is used. This, like everything else connected with soil acidity, must be further investigated. Meanwhile the Commission recommend that the pH value shall normally be determined in an aqueous suspension and when possible in a KCl suspension as well.

A second point is the carbon dioxide content of the water used. Ordinary distilled water as obtained in the laboratory contains a sufficient amount of CO_2 to give pH figures which are too much on the acid side. This is particularly the case with neutral and alkaline soils. When however, the water is aerated and so brought into equilibrium with the CO_2 pressure of the atmosphere, or when the water is boiled, better values are obtained. The figures quoted by Biilmann and Jensen (Vol. B, pp. 262–3) are interesting in this connection.

The proportion of water to soil has been a much disputed matter and the results of different works are in conflict. Some claim that the water: soil ratio is of no importance, and others show that considerable differences of pH follow differences in this ratio. Some light has been thrown on these discrepancies by Pierre (Soil Science Vol. 20, p. 285) whose results indicated that differences in pH may arise from differences in soil: water ratio when soluble substances are present in the soil, but that after washing the soil: water ratio is less significant. The matter has been investigated by Biilmann and Jensen (Vol. B, p. 252) and their results confirm those of Pierre. It is pointed out, however, by Biilmann and Jensen, that apart altogether from the influence of this ratio upon the pH value a ratio of 1 : 1 has practical conveniences when the quinhydrone electrode is used. This ratio is therefore recommended. The printed recommendations of the Second Commission (Vol. B, p. 81) suggest a soil: water ratio of 1: 2.5. It was however agreed at Groningen to ask the late Dr. Christensen and Dr. Biilmann to submit a critical report on this matter. I would suggest that the report of Biilmann and Jensen be accepted and that a ratio of 1 : 1 be adopted.

The Determination of pH

The methods that present themselves are colorimetric methods and electrometric methods. In electrometric methods a choice lay between the hydrogen electrode and the quinhydrone electrode.

There are three outstanding points in the Commission's recommendation.

First. The necessity of giving in published work full details of the method used. Small differences of technique may make considerable differences in result, and the discussion of working details is necessary for a two-fold reason; first, that readers may form a critical opinion of the validity of the figures; and second, that information may be accumulated as rapidly as possible which will facilitate the standardisation of our methods.

Second. While colorimetric methods are obviously useful an electro-

metric method must be the basis of any standard international method. Not only is the theoretical basis of the electrometric method more reassuring than that of the colorimetric method, but there exists in the laboratory much wellknown evidence that colorimetric methods cannot be relied upon for accurate work.

Third. The quinhydrone electrode should be used if possible in view of its convenience.

Soil workers generally have been very cautious in replacing the hydrogen electrode by the quinhydrone electrode and there has no doubt been every justification for this. Everyone however will regard the report of Biilmann and Jensen (Vol. B, p. 236) as being very reassuring. The chief points that arise in this connection are:

1. The comparison of the results obtained by the hydrogen electrode and the quinhydrone electrode. The report referred to make it clear that in general the agreement is very good. Certain French soils and certain Laterites are the only ones they have yet been able to discover to give discordant results, and there is nothing in these cases to indicate that the results obtained with the hydrogen electrode are any nearer the truth than those obtained with the quinhydrone electrode. The importance of investigating these discrepancies cannot be too strongly emphasized. It is not sufficient to dismiss one discordant result found among more concordant results by merely saying "This is an exception." The investigation of exceptional cases is of outstanding importance in arriving at an accurate understanding of ordinary cases.

2. The reproducibility of the results. The report makes it clear that repeated determinations with the quinhydrone electrode on the same soil give very concordant results. Even ten independent determinations on the same soil gave results with no significant differences between the highest and lowest.

The report of Biilmann and Jensen discusses many important practical points in the use of the quinhydrone electrode, and the whole report seems to justify its use in preference to the hydrogen electrode, and to support the findings in this respect of the Second Commission. It is probably admitted by everyone that the quinhydrone electrode should not be used for soils more alkaline than $pH = 8.5$. Such soils are, however, in the minority although they are admittedly important in certain localities.

In the Report of the Groningen Meetings, recommendations will be found for the determination of hydrolytic acidity and exchange acidity. The acceptance of the discrimination between these different types of acidity is far from being generally accepted. This however, should not preclude the use of the methods suggested for their determination, as the accumulation of such data is bound to be of importance in deciding the justification for classifying soil acidity in this way.

Finally, I would like to emphasize what I said at the beginning, that in the adoption of a generally recognized International Method it must be realised by all concerned that the method is only tentative, and is intended to give the best results that can be obtained in our present state of knowledge, to give concordant results between different laboratories, and above all to serve as a pivot of further work.

The following papers on

SOIL ACIDITY

were read:

Kuhn, S., and Scherf, E.
Two new indicator mixtures, the "Complex" indicator for pH 7.–012.0 and the "neocomplex" indicator for pH 4.0–10.0 and the field methods for the colorimetric determination of the pH of soils

Alway, F. J., and Nygard, I. J.
Differentiation between acidity and lime deficiency in the case of peat soils

Rost, C. O., and Fieger, E. A.
Effect of different kinds and amounts of liming materials upon the hydrogen ion concentration of the soil

Aarnio, B.
Die Einwirkung von adsorbierton Kationen auf die Bodenreaktion

Brioux, C., and Pien, J.
Lime-requirement of acid soils; practical value of the Hutchinson-MacLennan method; buffer power toward the bases

Snyder, E. F.
A comparative study of the quinhydrone and hydrogen electrodes for determining the pH values of soils

Page, H. J.
The relation between the state of saturation of the soil and its hydrogen ion concentration, with special reference to the action of "Physiologically acid" fertilizers

Olsen, C., and Lang, K. L.
Concerning the accuracy of the different methods of determining the hydrogen ion concentration of the soil

McKibbin, R. R.
Soil acidity and the phosphate ion

Healey, D. J.
Colorimetric measurement of the reaction of air-dried soils

Prianishnikow, N., and Askinasi, D. L.
Soil acidity and absorption capacity

Connor, S. D., Walker, G. P., and Plice, M. J.
Soil acidity and base exchange studies on two very acid soils

Askinasi, D. L., and Jarussow, S. S.
The determination of the potential soil acidity

Kuhn, S.
On the colorimetric measurement of the reaction of soils

Duley, F. L.
Easily replaceable calcium in relation to returns from liming

Kerr, H. W.
Nature of soil acidity, its determination and relation to plant growth

Kelley, W. P.
Base unsaturation in soils

Trénel, M.
Are there hydrogen ions in zeolites and soils which are directly replaceable?

Sewell, M. C., Latshaw, W. L., and Tague, E. L.
The effect of acid phosphates in soil reaction

Kreybig, L. V.
The action of superphosphate and Rhenania phosphate on the soils

Monday, 20th June, 10 A.M.

Chairman, Prof. A. A. J. de'Sigmond

Secretaries, Dr. M. Trénel and Prof. N. M. Comber

The following papers on

BASE EXCHANGE

were read:

de 'Sigmond, A. A. J., and Gleria, J. di,
On the different degrees of saturation of the absorbing complex (Humus-Zeolite) of the soil, and methods of their determination

Wiegner, G., and Jenny, H.
On basic exchange

Parker, F. W.
Methods for the determination of the amount and avidity of exchangeable hydrogen in soils

Sewell, M. C., and Perkins, A. T.
Base exchange studies in Kansas soils correlated with crop performance and fertilizer practice

Mattson, S.

The influence of the exchangeable bases on the colloidal behavior of soil material

Anionic and cationic adsorption by soil colloidal materials of varying $SiO_2/Al_2O_3-Fe_2O_3$

Conrey, G. W., and Schollenberger, C. J.

The effect of weathering on exchangeable bases as shown in the clermont silt loam profile

Humfield, H.

Replaceable soil potassium

Bradfield, R.

Factors to be considered in determining the saturation capacity of a soil

Discussion

Dr. W. P. Kelley said that in the determination of the absorbed NH_4 after treating soils with ammonium chloride he removes the excess of ammonium chloride with a non-hydrolizing and coagulating solvent, namely methyl alcohol.

Dr. Kelley further pointed out that in order to distinguish between solubility effects and the true exchange of bases it is necessary to determine the amount of base that the soil absorbs from the salt solution used. In some soils the bases which are dissolved by the salt solution exceed those which are really replaced.

Trénel points out that Wiegner also confirms in his paper that the base ions take part only to a very small fraction in the base exchange and asks Wiegner to explain with the help of his opinion, recently delivered. Trénel invites attention to the experiments of Wache Sevlog, Landes austalt, Berlin, from which it follows that unbased permutit possesses a considerably higher water content than the normal permutit. It seems also as if water enters into the molecules of the permutit in place of the removed bases. His own experiments, presented yesterday, regarding the systematic decomposition of permutit with carbonated water gave the same result. Trénel, therefore, cannot admit that the base removed from the permutit is replaced by exchangeable hydrogen ions (compare the paper of Trénel.)

Wiegner answers the question of Trénel to the effect that he also is of the opinion that the hydrogen ions occupy an exceptional position regarding the base exchange. The result that unbased permutit has a *higher water content than before is confirmed by Wiegner*. The fact that hydrogen ions act differently when exchanging as bases is explained by Wiegner as follows; hydrogen ions can occur highly hydrogenated as well as weakly hydrogenated. Besides it cannot be assumed that molecular water is

absorbed. Trénel replies that of course he is not of the opinion that water is combined in molecular form.

Professor Tjurin said:

"Referring to the methods now proposed for the determination of exchangeable bases, I should like to make some remarks based on the work of Russian colleagues. According to the principle, ascertained by Dr. Gedroiz in 1916, that exchangeable bases may be entirely replaced by any cation of neutral salts, if the successive treatment of soil with salt solution is continued a sufficient length of time, it is possible to apply *any neutral salt* for the determination of exchangeable bases.

"But *ammonium chloride is the most suitable salt to be applied to the soils containing no alkaline earth carbonate* for the reason that there is no difficulty with the determination of Ca and Mg whilst ammonium chloride can be readily removed before the determination of K and Na.

"If we bear in mind that NH_4 as absorbed cation is usually lacking in soil, we may regard the method proposed by Prof. Gedroiz in 1918 as a standard one. The usual modification of this method is described in Gedroiz's book translated now into German under the title: 'Chemische Bodenanalyse.'

"The simplified method with 0.05 *N* HCl proposed by Gedroiz in 1921, has the advantage of rapidity in leaching exchangeable bases from soil. Experiments made by some authors later (Bobko and Askinasi, Tjurin, Gemmerling) have shown that the method in some cases gives rather higher figures for exchangeable bases especially of Mg (Tjurin) than those obtained by the ammonium chloride method. But if only the determination of exchangeable Ca is wanted, the method in a lot of cases may be applied with good results. I believe that in cases of so-called 'humus' soils this method may be very suitable.

"In cases of soils containing carbonate of calcium (and magnesium) the method with *N* NaCl solution, proposed by Dr. Hissink, is to be regarded as more suitable. But in its original form the method of Hissink is not free from objections. Experiments made by the writer with this method have shown that in many cases the complete extraction of exchangeable Ca is not attained by treatment with one litre of sodium chloride solution, even if the quantity of soil is determined in 10 g. Some error may take place owing to some inconstancy of solubility of calcium carbonate during the process of filtration. To abolish these causes of possible errors, I propose to use the *direct estimation of the solubility of Calcium (and Magnesium) carbonate by titration of a certain part of the filtrate with 0.02 N HCl using methyl-orange as indicator.*[1] The treatment of the soil by *N* NaCl solution should be carried on until the content of extracted Ca (plus Mg) is the same as that estimated by the titration (as expressed in CaO equiv.)

[1] Russ. Jour. "Pedology," 1927, N 1.

"As regards the question of determination of the degree of saturation of the soil with bases, I should like to point out that it is necessary to consider the question of the pH value at which the soil may be regarded as saturated with bases."

Dr. MacIntire said:

"Dr. Hissink has noted the fact that an evolution of CO_2 is obtained when carbonate-free soil is digested with hot hydrochloric acid. The heating of a soil with hydrochloric acid, even a very dilute solution, without reduction of pressure, will result in an evolution of CO_2 which will continue for a long time. The reason for this has been conjectured but not proved. This point had been studied in this country, and in 1915 Mr. Willis and I published (Journal Industrial and Engineering Chemistry) a method for the determination of CO_2 in soils by agitation and aspiration without application of heat. That method is now embodied in the methods of the Association of the Official Agricultural Chemists (Book of Methods 1925 edition page 22). The amount of CO_2 given off as a result of the action of the cold acid (HCl or H_3PO_4) upon the soil organic matter is generally not measurable, and is always nugatory."

Prof. E. Truog, said:

"Without any intent to minimize the value of the excellent work that has been done on the soil solution, it may be well to point out that plants are probably not dependent entirely for their needs of mineral elements on the soil solution. The close contact which a root hair makes with a soil particle—sometimes called a growth fusion—creates in a sense a system within itself in which the plants feed independently of the soil solution. In this system the carbonic acid excreted acts at maximum efficiency because it immediately strikes the surface to be acted upon and also because the soluble products formed may be immediately absorbed."

Dr. W. H. MacIntire, said:

"This viewpoint seems rational as accounting for the increased growth of clover in a soil which has been limed, since related experiments show that the addition of lime results in a decreased occurrence of potassium in the rainwater percolates. It may be assured that the clover thrives in a medium which has been improved by the addition of lime and that the enhanced development of root hairs enables the plant to forage the better to obtain the larger supplies of potash required by greater growth. In this way the stimulated plants may be considered as more vigorously overcoming the repressive effect which lime additions have upon the solubility of the native potash of some soils."

Prof. E. Truog said:

"There appears to be some evidence that potassium, at least in part, goes over to a more insoluble form subsequent to its fixation as a replace-

able base in the colloidal complex. As a result of this, the potassium becomes less available, and it would seem that the more desirable field practice would be to apply potash fertilizers in small, frequent applications rather than the reverse."

Dr. MacIntire said:

"The work of Frear and Erb has not been cited, but it has a close bearing upon this point. Some of our findings at Tennessee seem to substantiate the conclusion that whereas a part of added potassium may be leached, a greater part becomes fixed by the soil. Some of the fixed potassium may be considered as fixed in a form which will yield fairly well to the pull exerted by the plant, whereas some of it may be considered as being rendered relatively insoluble. Using the observed parallel relative to the progressive decrease in the solubility of calcium and magnesium which had been fixed from caustic and carbonate additions, it may be assumed that fixed potassium will continue to pass into forms more complex and less soluble.

"Relative to the citation of the drainage water data from the Rothamsted plats as indicating that no manurial potash passes into the drainage waters, it should be remembered that those waters pass through a stratum of subsoil. In the Tennessee lysimeter studies it was found that a part of the added potassium passed from an unlimed surface loam, although the outgo of potassium was materially decreased by liming. Irrespective of any liberative effect within the surface soil, however, the passage of the percolates through a stratum of subsoil was followed by an equalized concentration of potassium in the percolates. The observations of Lyon and Bizzell also show that the addition of potassium salts fails to register an increased outgo of potassium where the percolates pass through an underlying zone of subsoil."

COMMISSION II

Monday, 20th June, 2:30 P.M.—Business Meeting

Chairman, Prof. O. Lemmermann, took the chair during the election of officers for the ensuing period of three years.

The following were elected:

President: Prof. A. A. J. de'Sigmond, Budapest

Vice Presidents: Profs. Aarnio, Ballenegger, Gedroiz, Lemmermann, McCool, Saidel and Wiegner

Secretaries: Profs. Askinasi and Comber, Dr. Görz, Dr. MacIntire, Dr. Truog, Dr. Zucker, Dr. Trénel

Committees were appointed as follows:

Soil Acidity and Absorption

Dr. Hissink, Prof. Lemmermann, Prof. Comber

Acid Extraction of Soils
Prof. Ganssen, Prof. Hendrick, Dr. Hissink
Plant Nutrients
Prof. Hoagland, Prof. Lemmermann, Dr. Niklas

JOINT MEETING WITH COMMISSIONS II AND IV

Chairman, Dr. O. Schreiner

Secretaries, Dr. Trénel and Prof. Comber

The following papers on

SOIL ORGANIC MATTER

were read:

Russell, J. C., and Burr, W. W.
Some fundamental factors which determine the organic matter and nitrogen content of virgin and cultivated soils

Page, H. J.
A critical study of methods for the determination of organic matter in the soil

Chapman, J. E.
The effect of organic matter on the tilth of a clay soil

Sievers, F. J.
The significance of nitrogen in soil organic matter relationships.

It was decided to ask Mr. Page and Dr. Shorey and Dr. Waksman to prepare the introduction to the discussion on Soil Organic Matter at the Leningrad Meetings and to authorize them to call a preliminary meeting of members interested before the Leningrad Meetings if they so desire.

Dr. J. D. Hissink, Vice President and General Secretary, reported upon the joint meeting of Commissions II and IV and also their meeting with Commission I as follows:

JOINT MEETING OF COMMISSION II AND IV

Tuesday, 14th June, 2:15 P.M.

Chairman, Dr. A. A. J. de'Sigmond

Secretaries, Prof. N. M. Comber, Dr. D. R. Hoagland, Dr. R. Görz and Dr. M. Trénel

Theme: NUTRIENTS OF THE SOIL

The president of the Second Commission, Dr. de'Sigmond, greeted the assembly and informed it of the death of Prof. Dr. Christensen and Prof. Dr. Vesterberg and the assembly stood in honor to their memory.

The meeting then proceeded with the program:

de'Sigmond, A. A. J.
  Discussion of the chemical determination of the nutritive material

Joffe, J. S.
  Availability of replaceable cations

Saidel, T.
  New contributions to the subject of soil solution

Page, H. J.
  The relation between the state of saturation of the soil and its hydrogen ion concentration with special reference to the action of "physiologically acid" fertilizers

Truog, E.,
  How plants feed

McHargue, J. S.,
  Significance of small amounts of inorganic elements in plants

Alway, F. J.,
  The deduction of sulfur-déficiency of soils by means of plants

Skinner, J. J.,
  The influence of phosphate, potash and nitrogen on the growth, quality and maturing of cotton

Discussion

Nobody offered to speak.

Dr. de'Sigmond suggested that a commission for study of pertinent questions be formed, to which Messrs. Hoagland, Lemmermann and Niklas should be appointed.

The meeting adjourned at 4:35 P.M.

JOINT MEETING WITH COMMISSIONS I, II AND IV

Saturday, 18th June, 10 A.M.

Chairman, Dr. A. A. J. de'Sigmond

Secretaries, Dr. N. M. Comber and Dr. M. Trénel

(A) Reports

Comber spoke about the preparations of soil samples for the pH determination.

Lemmermann talked about the physiological side of the question of soil acidity.

Hissink postponed his talk on soil adsorption until Monday (see report of the meeting).

The Groningen decisions were unanimously accepted without further discussion.

(B) Papers

Kerr, H. W.
  Nature of soil acidity, its determination and relation to plant growth

Kelley, W. P.
  Base unsaturation in soils

Trénel, M.
  Are there hydrogen ions in zeolites and soils which are directly replaceable?

Duley, F. L.
  Easily replaceable calcium in relation to returns from liming

Snyder, E. F.
  Comparative study of the hydrogen and quinhydro-electrodes for the determination of the pH values of the soil

Sewell, M. C.
  The effect of acid phosphates on soil reaction

Kreybig, L. B.
  The action of superphosphate and Rhenania phosphate on the soils

Healy, D. J.
  Colorimetric measurement of the reaction of air-dried soils

Plice, M. J., and Connor, S. D.
  Soil acidity and base exchange studies on two very acid soils

Saidel desists from reading his paper because it is getting too late.

(C) Discussion

Wiegner declares that Trénel's opinion about unbased permutit is not in agreement with the opinion of colloid chemistry and therefore declines Trénel's opinion. This discussion was continued, Monday, June 20.

JOINT MEETING WITH COMMISSIONS II AND IV

Monday, 20th June, 10 A.M.

Chairman, Dr. A. A. J. de'Sigmond

Secretaries, Dr. N. M. Comber and Dr. M. Trénel

Hissink read his paper on absorption of soil. Messrs. Kelley and MacIntire took part in the discussion.

The following papers were read:

Wiegner, G., and Jenny, H. (read by Wiegner)
  About base exchange

Novák, V.
  A contribution to the methods for the estimation of the exchangeable bases in soils

'Sigmond, A. A. J. de
Conclusions concerning the uniform preparation of soil extracts with hydrochlorid acid

Sewell, M. C., and Perkins, A. T. (by Perkins)
Base exchange studies on Kansas soils and their relation to crop production and fertilizer practice

Ganssen, R.
The operation of natural laws in the soil

Conrey, G. W.
The effect of weathering on exchangeable bases

Menszikowski
The zeolytic complex of the soil

Bradfield, R.
The use of electro dialysis in physico-chemical investigations of soils

DISCUSSION

Trénel points out that Wiegner also confirms in his paper that the base ions take part only to a very small fraction in the base exchange and asks Wiegner to explain with the help of his opinion, recently delivered. Trénel invites attention to the experiments of Wache from which it follows that debased permutit possesses a considerably higher water content than the normal permutit. It seems also that water enters into the molecules of the permutit in place of the bases. His own experiments, presented yesterday, regarding the systematical split of permutit with carbonated water gave the same result. Trénel, therefore, cannot admit that the base removed from the permutit is replaced by exchangeable hydrogen ions (compare the paper of Trénel).

Wiegner answers the question of Trénel to the effect that he also is of the opinion that the hydrogen-ions occupy an exceptional position regarding the base exchange. The result that debased permutit has a higher water content than before is confirmed by Wiegner. The fact that hydrogen ions act differently when exchanging as bases is explained by Wiegner as follows: Hydrogen ions can occur highly hydrogenated as well as weakly hydrogenated. Besides it cannot be assumed that molecular water is absorbed. Trénel replied that of course he is not of the opinion that water is adsorbed in molecular form.

Dr. A. A. J. de'Sigmond addressed the meeting as follows:

"This is the last sectional meeting of Commission II, consequently we shall have to elect the Chairman, the Vice-Chairman and Secretaries as well as the Referees of the different special problems, which require cooperative experimental work. It seems to me practical to do this now, and not at the end of the general meeting, because at that time it is very likely that most of those attending the meetings may have left.

"Before leaving the chair I take pleasure in extending my thanks to every one of the members of the Commission, and especially to the Referees and those members who by their valuable cooperation made our sectional meeting so rich in prominent lectures and also enabled us to formulate useful conclusions and make promising beginnings for future work.

"We learned also, that the way to prepare for the meeting of the Congress was by special preliminary meetings which has proved very satisfactory, because at these special meetings we have more opportunity to discuss important questions than in the Congress meetings. The latter can, in this way, easily decide the conclusions proposed, because agreement has been reached at the preliminary meetings.

"I thank you again for your sympathetic assistance, which enabled me as Chairman of the Commission to lead our sectional meeting. I may also add the thanks of my Vice Chairmen and of the Secretaries. And now may I introduce Prof. Dr. O. Lemmermann to you who will preside during the election of the Chairman for the period extending from the First Congress to the next, or Second Congress. Thank you."

The meeting adjourned at 12:30 P.M.

COMMISSION III

SOIL BIOLOGY AND BIOCHEMISTRY

President

DR. J. STOKLASA, Polytechnical School, Prague, Czechoslovakia

Vice Presidents

DR. S. A. WAKSMAN, New Jersey Agricultural Experiment Station, New Brunswick, New Jersey
DR. H. NIKLAS, Agricultural College, Weihenstephan, Germany
DR. G. ROSSI, Agricultural Institute, Portici, Italy

Secretaries

DR. D. W. CUTLER, Rothamsted Experimental Station, Harpenden, England
DR. A. NEMEC, Polytechnical School, Prague, Czechoslovakia
DR. E. B. FRED, University of Wisconsin, Madison, Wisconsin
DR. E. G. DOERELL, Polytechnical School, Prague, Czechoslovakia

Dr. S. A. Waksman, Vice President of Commission III, reported for the Secretary of this commission as follows:

Members of Commission III, Washington Congress

Jacob Lipman	New Brunswick N.J.
Selman A. Waksman	New Brunswick, N.J., U.S.A.
Prof. Dr. H. Niklas	Weihenstephan Germany
E. B. Fred	Madison, Wis
A. G. Lochhead	Ottawa, Canada
A. Kreybig Ludwig	Csorhátszurány Hungary
E. E. Uspensky	Russia Moscow
J. Ziemiecka	Poland Warsaw
Walter G. Sackett	Fort Collins, Colorado.
I. L. Baldwin	Madison, Wis. U.S.A.
Allan B. Cutley	Sydney, Australia
W. L. Owen	Baton Rouge La
Margaret B. Church	Washington, D.C.
Fr. Weis	Copenhagen
Jakob Blom	Copenhagen.
Elias Melin	Stockholm
William H. Wright	Madison, Wisconsin, U.S.A.
Charles Thom	Washington D.C.
F. M. Schertz	Washington, D.C.
F. E. Allison	Washington, D.C.
Arao Itano	Okayama-Ken, Japan.
W. Rudolfs	New Brunswick NJ
Thos. F. Manns	Newark Del
Marshall Manns	Newark, Del.
Leon A. Bradley	Amherst, Mass.
M. H. Cubbon	Amherst, Mass.
H. G. M. Jacobson	New Haven Conn.
Lewis W. Erdman	Ames, Iowa.
J. W. Shunk	New Brunswick N.J.
[illegible]	New Brunswick N.J.
Wm. A. Albrecht	Columbia Mo
P. G. Krishna	Secunderabad (Dn) India
H. P. [illegible]	West Palm Beach, Florida
A. J. Boyd [illegible]	State College of Wash. Pullman
F. C. Gerretsen	Agr. Exp. Station Groningen Holland.

Nathan R. Smith	U. S. Dept. Agric. Washington, D.C.
Robert L. Starkey	Agricultural Experiment Station, New Brunswick, N.J.
Florence G. Gentey	Agricultural Experiment Station, New Brunswick, N.J.
René J. Dubos	New Brunswick N.J.
Charles E. Skinner	Univ. of Minnesota, Minneapolis
[illegible]	[illegible] Manuel (Experiment Station Chaparra) Cuba
M. R. Raines	U.S. Dept. Agri. - Washington, D.C.
Lewis Leonard	" "
E H Frothingham	Appalachian Forest Experiment Station, Asheville, N.C.
C R [illegible]	"
W. Eyre	U.S. Dept. Agr. Washington D.C.
R. Henry Marriott	Phila. Pa. - U.S.A.
Thomas C. Richmond	Columbus, Ohio
O. H. Sears	Univ. of Illinois, Urbana, Ill.
Harold W. Batchelor	Agr. Exp. Station Wooster Ohio.
R. V. Allison	" " " Everglades, Belle Glade, Fla.
R. M. Barnette	" " " Gainesville, Fla.
E J Russell	Rothamsted Experimental Station.
H. J. Conn	Geneva, N.Y.
A. L. Sessions	~~A L Sessions~~ New Jersey Exp. Sta.
Hideo Miura	Corea, Japan
A J Findlay	Dept. of Agriculture Nigeria West Africa.
T. H. Knowles	Gold Coast. Br. West Africa.
R D Rands	U.S. Dept. Agr. Wash. D.C.
Carl Hartley	" " " "
Leonard F. Kellogg	Ohio Valley For. Exp. Sta. U.S.F.S.
Ferdinand W. Haasis	Appalachian Forest Exp. Sta. (U.S. Forest Service) Asheville, N.C.
J. T. Prince	N.H. Exp. Sta. Durham N.H.
Franklin W. Marsh	U. S. Dept. Agr. Washington, D.C.
J. G. Holdaway	Adelaide, Australia

PROCEEDINGS OF COMMISSION III

DR. S. A. WAKSMAN, Vice President

In all, six special sessions were held by Commission III including the session on soil organic matter, in which Commissions II, IV and VI also participated. The sessions were arranged according to the most outstanding problems in soil microbiology at the present times. The number of papers presented at each session ranged from 6 to 15. The average attendance was about 50, ranging from 35 to 65. Each session was led by a special leader, particularly interested in the subject under consideration. Only a few of the papers, of authors which were absent, were presented before this commission due to lack of time. Otherwise the commission completed the whole of its program.

The First Session dealt with the direct microscopic and cultural methods used in soil microbiology at the present time. In his address on the direct method in soil microbiology, Prof. Winogradsky emphasized the great importance of considering the nature and activities of the soil microorganisms directly in the soil and not in artificial media. Particular attention was called to the fact that most of our present information on the soil population is largely of a phase of General Microbiology than of a specific applied subject, namely soil microbiology. In the other papers presented at this session and especially in the paper of Dr. Lochhead, the session leader, and in the discussion following, emphasis was laid upon the necessity of correlating the results obtained by the various methods of analysis and of making the details of the methods somewhat more definite, so that the results obtained in different laboratories could be comparable. A committee was appointed consisting of Mr. Bonazzi of Cuba and Dr. Lochhead of Canada to consider these suggestions. This committee recommended, after consultation with other workers in the field, to appoint a permanent committee which shall look after the various methods used in microbiological soil investigations in an attempt to correlate them and make them more uniform. A permanent committee for this purpose was appointed at the last session; this committee consisting of Dr. E. B. Fred, University of Wisconsin; Mr. A. Bonazzi, Cuba; Dr. Lochhead, Canada; Mr. Thornthon, Rothamsted Experiment Station, England; Mme. V. Ziemiecka, Institute Pasteur, Paris.

The Second Session dealing with the soil population emphasized particularly the fact that numerous groups of microorganisms, in addition to bacteria, are present in the soil and play there important rôles. It is sufficient to mention the algae, fungi, including also pathogenic forms and mycorrhiza fungi, protozoa, nematodes and other invertebrate animals.

The Third Session was devoted to problems of nitrogen-fixation both by non-symbiotic and symbiotic bacteria. Prof. Niklas emphasized the use

of the Azotobacter method for determining the lime, phosphorus and perhaps potassium requirement of soils. It is first essential to establish whether specific bacteria are present in the soil and in what abundance. If they are absent in the soil, one should consider the conditions which will favor or prevent the development of the particular organism. Bacteriological methods can be readily utilized as an aid in determining the fertility of the soil. The relationship of the legume bacteria was emphasized in various contributions.

The Fourth Session was devoted to the various transformations which nitrogen undergoes in the soil: the decomposition of organic matter with the formation of ammonia, the influence of the non-nitrogenous constituents of the organic matter upon the formation of ammonia, the formation of nitrites and nitrates, the decomposition of urea, the formation of proteins by microorganisms were discussed in detail. Prof. Beaumont suggested that some attempt should be made to standardize the terminology of bacteriological processes. In the literature on nitrification, for example, there is a complete lack of uniformity in expressing the quantities measured, as indicated by the following usage:

1. Pounds of total nitrogen per acre.
2. Pounds of nitrate nitrogen per acre.
3. Parts per million of total nitrogen on oven-dry basis.
4. Parts per million of total nitrogen on moist basis.
5. Parts per million of nitrate nitrogen.
6. Various percentage expressions.
7. Milligrams of nitrate nitrogen in 100 g. of soil.

It is proposed to establish a uniform system for calculating and recording the results.

The Fifth Session dealing with the transformation of organic matter in the soil, held jointly with several other commissions, tended to throw considerable light on the nature of soil "humus." According to Dr. Page, the soil humus exists in the form of a lignin-protein complex which makes the nitrogenous material resistant to decomposition. Dr. Waksman pointed definitely to the nature of the nitrogenous complexes of the soil which originated through the synthesizing activities of microorganisms, the celluloses and hemicelluloses being thereby used as sources of energy. Dr. Sievers called attention to the tremendous economic problems involved in the utilization of straw residues. The plowing under of the straw leads to a nitrogen minimum. The removal and frequently burning of the straw leads to an exhaustion of the soil organic matter. A combination of green manure and straw residue was found to solve the problem practically. The preparation of synthetic manure by composting straw with artificial fertilizers has also received considerable attention.

The final two sessions were combined into one, a Sixth Session. Dr.

Clark presented a theoretical bases for the study of oxidation-reduction processes in the soil. Dr. Blom developed the various chemical processes involved in the reduction of nitrates in nature. A series of reactions were suggested which explain and correlate the first steps in the fixation of nitrogen with the reduction of nitrates. The rôle of microorganisms in the precipitation of iron and oxidation of sulfur received considerable attention. Rudakov called attention to the fact that bacteria exist in the soil, which are capable of reducing inorganic phosphates. Gerretsen emphasized the value of microbiological methods of soil analysis to important soil problems, such as partial sterilization of soil for the destruction of various fungus pests. Sir John Russell finally called attention to the numerous economic processes which were benefited by a better understanding of the microbiological processes in the soil.

Commission III elected its past President, Prof. Dr. J. Stoklasa, as honorary member of the commission. For the next Congress that will take place in Russia, in 1930, the following officers were elected:

President—Prof. V. L. Omelianski, Leningrad, Russia

Vice Presidents—Prof. C. Barthel, Stockholm, Sweden
Prof. D. W. Cutler, Harpenden, England
Prof. Niklas, Weihenstephan, Germany
Prof. S. A. Waksman, New Brunswick, N. J., U. S. A.

Secretaries—Prof. E. B. Fred, Madison, Wis., U. S. A.
Dr. A. G. Lochhead, Ottawa, Canada
M. Guittonneau, Paris, France
Prof. V. Uspenski, Moscow, Russia
Prof. A. Rippel, Göttingen, Germany
Prof. A. Itano, Ohara Inst., Japan
Dr. Von Kreybig, Budapest, Hungary
Dr. Docrell, Prague, Czechoslovakia

The nature of the progress made by Commission III differs fundamentally from that of the other commissions, due to the very nature of the subject under consideration. While the soil physicist, the chemist, the geneticist can adopt certain methods of study and analysis, can agree upon general principles and can profit greatly from collective work, from general routine procedures, the soil biologist has other paths to follow. The microbiologist, dealing with life processes, is more of an individualist than the other soil workers, he has to depend more upon his own resources, work out his own methods and suggest his own interpretation. So far from agreeing upon standard procedures, he is not even willing to admit that an attempt can be made at the present time to make uniform the methods of investigation and analysis. This matter was amply brought out in the first sessions of this commission. The problems which face this

commission are not of a nature than can be standardized. They are problems facing any group of investigators who attempt to unravel a series of complicated biological processes and what is more complicated than the soil population and the numerous interrelated processes brought about by this complex population. In this respect any attempt at standardization may only hamper further progress.

The soil biologist has been recently challenged that his contributions are largely concerned with General Microbiology while we do not have as yet any applied Science of Soil Microbiology. This is, however, largely a play of words rather than a matter of fundamental difference. It is very difficult to distinguish in any science where the natural phenomena end and where the applied processes begin. This is true of Microbiology as a whole as well as of its various subdivisions.

The aim of the soil Microbiologist is pure research, without any practical end point in mind. However, as a result of careful study and investigation, the practical application of soil microbiology to farm practice has been considerably advanced and placed upon a sound practice.

COMMISSION IV

SOIL FERTILITY

President

DR. E. A. MITSCHERLICH, University of Königsberg, Germany

Vice President

DR. K. ZIJLSTRA, Agricultural Experiment Station, Groningen, Holland

Secretaries

DR. O. ARRHENIUS, Agricultural Experiment Station, Stockholm, Sweden
DR. D. R. HOAGLAND, University of California, Berkeley, California
DR. M. TRÉNEL, Berlin, Germany
DR. K. ASO, Imperial University, Tokyo, Japan

Dr. D. R. Hoagland reported a separate session concerned with a symposium on Soil Plant Interrelations and Dr. M. Trénel reported a joint meeting with Commission II. Their reports follow:

PROCEEDINGS OF COMMISSION IV

DR. D. R. HOAGLAND, Secretary

This Commission held only one separate session, in addition to one joint session with Commission II. The separate meeting was concerned with a symposium on Soil and Plant Interrelations. The following program was carried out:

Time: Wednesday, June 15, 1927 (afternoon)
Chairman, Dr. D. R. Hoagland
Secretary, Dr. M. Trénel

Papers presented:

(1) Burd, California
An important aspect of studies on the soil solution

(2) Parker, Alabama
Recent studies on the phosphate content of the soil solution and its relation to the phosphorus nutrition of the plant

(3) Hoagland, California
Recent experiments concerning the determination of the adequacy of artificial culture solutions and of soil solutions for the growth of different types of plants

(4) Niklas, Weihenstephan
The effect of a twelve-year potassium manuring upon plants and soil

(5) Farr, Missouri
The effect of Ca and H ions upon root hair growth

Following the reading of these papers an extensive discussion occurred, which was participated in by Burd, Page, Hoagland, MacIntire, Fraps, Truog, Parker, Görz, Farr, and others. Further reference to this discussion will be found in the special numbers of "Soil Science" (Vol. 25, No. 1.).

PROCEEDINGS OF COMMISSION IV

DR. M. TRÉNEL, Secretary

KOMBINIERTE SITZUNG DER II UND IV KOMMISSION

am Dienstag, den 14. Junim 1927, nachmittags 2.15

Thema: Nährstoffe des Bodens

Vorsitz, Dr. A. A. J. de'Sigmond and Dr. M. M. McCool

Sekretaere, Drs. N. M. Comber, D. R. Hoagland, G. Görz und M. Trénel

Der Praesident der 2. Kommission, de'Sigmond, begrüsst die Anwesenden und teilt den Tod von Prof. Dr. Christiansen und Prof. Dr. Festerberg mit. Die Anwesenden erheben sich zum Gedenken von ihren Stizen.

Die Versammlung tritt dann zur Tagesordnung ueber.

(1) de 'Sigmond, A. A. J.
Chemische Bestimmung der Nährstoffe des Bodens

(2) Joffe, J. S.
Die Zugänglichkeit der austauschbaren Kationen

(3) Saidel, T.
Neue Beiträge zu unsrer Kenntnis von Bodenlösungen

(4) Page, H. J.
Die Beziehungen zwischen Sättigungsgrad des Bodens und Wasserstoffionenkonzentration mit besonderer Berücksichtigung der Reaktion physiologisch saurer Dünger

(5) Truog, E., Wisconsin
Wie ernähren sich die Pflanzen

(6) McHargue, J. S., Kentucky
Die Bedeutung geringer Menge anorganischer Elemente in Pflanzen

(7) Alway, F. J., Minnesota
Nachweis von Mangel an Schwefel in Böden mit Hilfe von Pflanzen

(8) Skinner, J. J., Washington, D. C.
Der Einfluss von Stickstoff, Phosphat und Kali auf das Wachstum, Qualität und Reifung der Baumwolle

Diskussion

Es meldet sich niemand zum Wort.

de'Sigmond schlaegt vor, eine Kommission zur Prüfung der in Rede stehenden Fragen zu bilden, der die Herren Hoagland, Lemmermann und Niklas angehoeren sollen.

Schluss der Sitzung 4.35 Uhr nachmittags.

COMMISSION V

CLASSIFICATION, NOMENCLATURE AND MAPPING OF SOILS

President

Dr. C. F. Marbut

Presidents of the Subcommissions

Subcommission I

CLASSIFICATION OF SOILS IN EUROPE

Dr. B. Frosterus, Geological Survey of Finland, Helsingfors

Subcommission II

CLASSIFICATION, NOMENCLATURE, AND MAPPING OF SOILS IN THE AMERICAS

Dr. C. F. Marbut, U. S. Department of Agriculture

Subcommission III

THE INTERNATIONAL SOIL MAP OF EUROPE

Dr. H. Stremme, Technische Hochschule, Danzig, Germany

SUBCOMMISSION IV

THE CLASSIFICATION OF ALKALI AND SALTY SOILS

DR. A. A. J. DE'SIGMOND, Technische Hochschule, Budapest, Hungary

Secretaries of the Commissions and Subcommissions

SUBCOMMISSION II

MR. F. J. MARSCHNER, Washington, D. C.

SUBCOMMISSION III

DR. W. WOLFF, Germany
DR. A. TILL, Austria

SUBCOMMISSION IV

DR. E. SCHERF, Budapest, Hungary
DR. R. BALLENEGGER, Budapest, Hungary

No report of the general proceedings of this Commission was submitted but the following reports of the Subcommissions were presented:

REPORTS OF SUBCOMMISSIONS

SUBCOMMISSION II

CLASSIFICATION, NOMENCLATURE, AND MAPPING OF SOILS IN THE AMERICAS

SUBCOMMITTEE FOR NORTH AND SOUTH AMERICA ON THE CLASSIFICATION AND NOMENCLATURE OF SOILS

OUTLINE OF A SCHEME FOR THE STUDY OF SOIL PROFILES

DR. C. F. MARBUT, Chairman

The following brief outline of the discussions on classifications in and out of the Committee meetings in Rome followed by a description of the principal features of the great soil groups of the world so far as they have been defined up to date is presented here with the request that an attempt be made by all soil specialists to describe the profiles of the soils selected as representative of any given group in such a way that they may be identified as members either of one of the well established groups or of an entirely new group of soils, one not hitherto recognized.

SOIL CLASSIFICATION

The discussions on the Classification of Soils in the several meetings of the Fourth Committee at Rome made it clear that, while the whole

matter is still in a somewhat formative stage, there is generally a well defined conviction among those soil specialists who have given most attention to the matter that any soil classification that will meet what may be called world-wide demands must be *fundamentally scientific.*

By this statement is meant that the classification must be based on studies of the soil, made for the single purpose of finding out the truth about its characteristics with no reference whatever to other considerations.

It was also clear that the members of the committee were convinced that the scheme must be based on soil characteristics, rather than on a series of causes, assumed, with or without reason for such assumption, to have produced those characteristics. This opinion seemed to be based on the recognition by all present that in all sciences, including soil science, the first effort, in the development of a science, should be directed to the accumulation of as much knowledge as possible concerning the bodies with which the science is concerned; that for convenience of handling these bodies must be grouped in some kind of order before the investigations have progressed far and that in this case the grouping (classification) must of necessity be based on features rather than causes. It was further recognized that everything possible should be done to promote the accumulation of soil knowledge and the classification scheme should be of such a character as to promote this accumulation. It was thought that a scheme based on features would be better in this respect than one based on supposed causes.

It was rather generally recognized that when soils have been carefully studied, their fundamental features determined and when they are finally grouped into a series of categories according to the relative comprehensiveness or inclusiveness of the several features, such an arrangement will be found to accord fully with the causes which have produced the features whatever they may be. It has also become fully recognized as a basic principle, although not specially discussed at Rome, that the causes which have produced soil features can be fully determined only through an independent determination of the distribution of each of the important soil features and a correlation of these with the distribution of the various forces and conditions prevailing on the earth's surface. This makes the accumulation of detailed information of soil characteristics absolutely necessary and however important a classification according to causes or genesis may be it cannot be constructed until great progress has been made in this accumulation. In the meantime the bodies defined as units must be grouped, and the only available sound basis is that of the accumulated characteristics. If the above statement be true a grouping on this basis, adjusted from time to time in accordance with the accumulation of knowledge, will become in the end, automatically, a grouping according to causes.

Within recent years a well defined opinion has developed among those chiefly concerned with classification that the search for causes should be prosecuted with undiminished vigor but that this should be done for the *purpose of explaining the existence of soil features and not for classifying the soils.*

Older schemes of Classification not satisfactory: Within the last few years a good deal of dissatisfaction with the older schemes of classification based on "origin" (geological) or causes (climatic and vegetative) has been more or less definitely expressed. There seems to be two principal reasons for this change in point of view. One of these is the conviction that the science of the soil should adjust its methods and point of view to those long maintained in the other Natural History Sciences.

The classification bases in all of the latter are internal rather than external. They are in all cases made up of features inherent in the objects themselves rather than based on forces or conditions outside the objects which are supposed to have had more or less determining influence in producing these features.

The other reason is based on a recognition of the inadequacy of the two principal bases of classification heretofore used. The older basis was geological. In the early stages of soil investigation, when it was local entirely and before any attempt whatever had been made to construct a scheme of classification that would serve for a wide area, a close relationship between soils and geological formations and processes was found and it is not surprising that this relationship was expressed in the scheme of classification. It is to be expected that before any considerable progress had been made in accumulating soil knowledge students would turn for help to what seemed most likely to give it. Geological science, the earth science most closely related to soil science, had already reached an important stage of development.

With increasing knowledge however the unmistakable evidence of the complete failure of this local relationship to manifest itself in broad soil relationships was accumulated in such mass and of such convincing quality that it could not be ignored. It was evident that if geological features were retained as bases for local soil grouping something else would have to be used as a basis for the grouping into broad groups if such broad grouping were to show any sort of relationship of actual soil features. This however could not be done logically since a logical scheme should show a uniform idea running through all its categories. It should not consist of parent materials in part and of soil features independent of parent materials in some other part. The same theme should run through the whole scheme.

The dissatisfaction with the climatic basis, the first one proposed to replace the geological, was based on the recognition of its inadequacy in an entirely different respect from that in which the old basis was found

wanting. It became evident with increasing accumulation of soil knowledge that a very close relation exists between climatic features and the broadest most widely prevalent features of the soil and even of those features that belong in a category secondary in breadth of inclusiveness to the first, but that climatic features could in no way account for local features of the soil.

An increasingly clear recognition of these relationships has convinced many of the most serious students of the subject that soils must be classified entirely on the basis of their features. Along with this has come the further realization that the fundamental categories of such a scheme must cover features of *normally developed* or *well developed* or *mature* soil individuals. This is merely a further approach, in soil classification, to the principles on the bases of which the classification of other natural bodies, especially plants and animals, stands. Since soils are not organic beings the application to them of the word *mature* may be of doubtful justification but that there exists in soils a group of characteristics that are comparable to those which in organic beings is connoted by the term mature there can no longer be any doubt. We may designate soils characterized by them as those having *well developed characteristics* if it is thought advisable to avoid the use of the word *mature*.

It is manifest that if these features be a product of progressive development they can be found only in situations where such development has been possible. While we cannot pretend to know the conditions under which all the factors of such development may operate normally we may be sure that their product can be found only in situations where the material which is being developed, or has been developed into a soil, has lain in an undisturbed condition for a long time. Such situations cannot be found in river valleys subjected to frequent flooding and the accumulation of new materials through sedimentation nor can they be found on steep slopes where active erosion is, and has long been, in progress and where more or less movement due to gravity has taken place.

They can be found only on smooth uplands, preferably undulating to gently rolling spots or areas where the level of permanent ground water lies at a depth of six feet or more. In every region the student who is beginning the investigation of its soils should determine the characteristic features of the profile of the well drained deeply weathered upland soils and accept that profile as the mature profile of the region. This can be considered as the *standard* profile and this soil can be accepted as the typical, providing the texture is neither sand nor an extremely heavy clay. The associated soils may be described by comparison with this as a standard.

Recent studies of soil profiles developed under a wide range of geographic conditions has brought to light the existence among them of two fundamentally different kinds of differences. These may be called:

(1) differences in *kind* and (2) differences in *degree of development.* The former concern mature soils only and the differences are those of well defined characteristics. The latter concern soils with imperfectly developed profiles so that differences are those not of different kinds of features, but of the same kinds of features imperfectly developed. The imperfection of development may extend to complete absence of a given feature in extreme cases. These are *immature soils.*

Soils with fundamentally different kinds of features or profiles occupy regions more or less widely separated from each other and in which different geographic conditions prevail. Soils with profiles differing only in the degree or perfection of the development of their features occur in the same region and in very close association. Mature soils are found associated with immature, but fundamentally different kinds of mature soils are not found in the same region. This is a necessary consequence of their immobility.

The Study of Soil Profiles

The first thing to do in any region or locality therefore is to locate a spot where the surface is smooth, preferably not flat, and where water does not accumulate either on the surface or in the subsoil. In other words the spot should have good surface drainage and the permanent water-table should stand at a depth of 6 feet or more.

Virgin soil.—In order that the natural soil from the surface downward may be examined the spot or spots should be covered with native vegetation though not necessarily in full development. In any given region a spot that is not cultivated and has not been cultivated for 50 years or more should be selected. Where such localities cannot be found it should be made clear that the soil was examined in a cultivated area and the description should differentiate the undisturbed from the disturbed part of the section.

The examination of the soil section, after the locality has been determined upon, should proceed in a systematic way somewhat as follows:

1. *Texture:*

   Examine carefully the successive layers of horizons differing in texture, or the fineness or coarseness of the material. The examination should extend to a depth of at least 5 or 6 feet. Describe the texture of each layer and its thickness.

2. *Color:*

   Examine the successive layers which you would differentiate according to differences in color, describing each and giving thickness.

3. *Structure:*

   Examine carefully the several layers that differ according to structure, defining structure as the kind and size of soil particle aggregation

and noting especially horizons with *fine granular structure* (granules about the size of bird shot or smaller) *coarse granular structure* (granules ranging up to half an inch or more in diameter and usually more angular or irregular in shape than the granules making up the fine granular structure); *layered or platy structure* in which the material splits into thin plates (this is not to be confused with stratification); *buck-shot structure* in which the soil on drying breaks up into angular fragments (found to characterize heavy clays usually having a considerable percentage of lime); *single-grain structure* in which the material is like flour or sand with no aggregation of particles.

4. *Consistency:*

Determine the successive layers or horizons differing in consistency (stickiness, friability, plasticity) describing each and its thickness.

5. *Compactness:*

Determine the relative compactness of the several layers measuring it by the degree of resistence to penetration by a pointed instrument.

6. *Cementation:*

Determine whether resistance to penetration is due in any horizon to cementation and if so the probable cementing material (light colored or reddish, very strongly cemented or weakly cemented).

7. *Chemical composition:*

While the determination of the chemical composition of the various parts of the soil section or profile cannot be performed in the field by the usual field methods, there are certain features that may be determined in at least a qualitative way. Field examination can detect the presence of horizons with concentrations of organic matter or of salts of the alkalies and alkaline earths.

I. Organic matter. Of this there are two kinds to be looked for.[1]

(a) The organic matter in the surface soil is recognized by the dark color, and the approximate relative percentage present is indicated by the intensity of the dark color. The determination of the thickness of the dark-colored layer in the virgin soil is very important.

[1] The organic matter referred to here is that contained *in the soil* and not that lying *on the soil.*

In forested regions there is usually a layer of organic debris on top of the virgin or uncleared soil. In regions with a cool climate it consists of forest debris and various mosses, is usually very slightly if at all decomposed and has a brown rather than black color. It ranges up to a foot or more in thickness. It is the "Rohhumus" of German soil literature. There may be a thin layer of dark colored well decomposed organic matter at the bottom, immediately overlying the mineral soil, but it is not generally present.

In temperate and tropical latitudes, especially in the great deciduous forest regions, the leaf mold cover of the virgin soil is usually thin and the bottom part is rather well decomposed, quite dark in color and granular.

In the grass lands there is rarely a layer of organic matter of any kind on the soil.

(b) In some soils, usually confined to regions with a cool moist climate, there is present, at a depth ranging from 6 inches or less to somewhat more than a foot, a layer of brown or coffee-brown organic matter ranging from a film to 6 or 8 inches in thickness.

II. Salts of the alkalies and alkaline earths. These accumulate in the soil under favorable conditions. Since the work here contemplated is general and the soil characteristics dealt with are those of wide regional distribution, we may practically neglect all salts except the carbonate of lime. The more soluble salts constituting what is usually known as "alkali" are present in relatively small areas and may be neglected, or the soils in which they occur may be designated merely as alkali soils.

Horizons of lime carbonate accumulation may be identified readily by anyone and should be looked for where the rainfall is less than 17 to 18 inches per year in cool to cold climate and 30 inches per year in hot or very warm climates.

The unweathered material beneath the soil in any region, arid, subhumid or humid may have a high percentage of lime carbonate but such material should not be confused with the horizon of true lime carbonate accumulation.

III. Sesquioxides. These accumulate in the soil under favorable conditions. Since accumulations of aluminum hydroxide are not readily identified by the usual field methods these may be left out of consideration. We are concerned, therefore, with accumulations of iron oxides.

These occur in two forms: (a) accumulation of finely divided or colloidal iron oxide (hydroxide). The degree of concentration may be determined, within a rather wide range of error, by the intensity of the red color. At any rate the existence of red horizons in the soil profile should be noted and should be illustrated with samples, even though they be small.

(b) Accumulations of ironoxide concretions or large masses, usually porous or slaglike. This does not refer to iron-stone slabs or ferruginous sandstone layers which may be found in many places in the parent geological formations. The accumulations referred to here are to be found either in the B horizon or at the top of the C horizon.[1] In hot countries they take the form of thick masses of porous slaglike iron oxide lying at depths ranging from somewhat less

[1] In standard soil descriptions for humid regions the light-textured surface horizon is designated as the A horizon, the underlying heavier textured layer as the B horizon and the third layer, consisting of the unweathered or incompletely weathered geological formation, as the C horizon. The A and B horizons constitute the real soil profile, the Solum horizon of Frosterus, while the C horizon is part of the parent geological formation not made significantly lighter or heavier in texture by soil making processes.

than 3 to more than 15 feet, or they may consist of fragments scattered over the surface.

The succession of texture layers or horizons constitutes what is usually called the *soil profile* or *soil section.* In regions where the rainfall is sufficient to wet the soil to an indefinite depth and maintain in it a predominant downward percolation of water throughout a large part or all of the year, regions ordinarily called humid, it will be found that the well developed soil has in general a surface layer of relatively light texture, a second layer heavier in texture than the first and a third layer usually looser than the second and probably in most cases lighter in texture but in some cases it may be heavier. Where this third horizon cannot be identified on the basis of texture this can usually be done on the basis of color (see below).

The A horizon may have, and in the virgin soil usually does have, more than one color horizon. These are designated as subhorizons of the A horizon usually as the A_1 and the A_2 horizons. In the latter case the C horizon may consist of two subhorizons differentiated on the basis of the extent of leaching, into a C_1 horizon which has been leached of such carbonates as the parent geological material may have originally contained and a C_2 horizon that has not been changed at all.

In structure the subhorizons will usually differ one from another.

Compact layers, not including under this designation those cultivated soils in which the surface soil through mismanagement becomes "baked" on drying, are usually found in the lower part of the A horizon, in the lower part of the B horizon or at the top of the C horizon.

In any given region the A, B and C horizons will vary in relative thickness, relative difference in texture between A and B, in color and in the geological features of C. The range of these variations in well developed soils should be determined.

Wherever chemical data such as the *chemical composition* or the reaction of the several horizons of any soil can be obtained they should be submitted. It is generally recognized however that old-style analyses of "soil" alone or of "soil" and "subsoil" are practically worthless for classification purposes or for type definition. In every case it should be stated whether the analysis is a *fusion* or an *acid digestion* analysis. The method of determining the reaction of the soil, the horizon examined and the numerical results should be given.

Soils With Imperfectly Developed Profiles

In some regions it will be found that the well developed soils, soils with texture profiles in which the A and B horizons differ distinctly, will occupy a relatively small part of the whole land area. The rest of the area will be occupied by soils in which the difference in texture between the A and B horizons is very slight or none at all, or on the other hand such differences

as exist may prove to be due to geological processes rather than soil making processes.

Imperfectly developed profiles may be due either to the recency of the accumulation of the parent soil material or to the presence of excessive moisture throughout the period during which the soil has existed. The latter soils are found in regions where the water-table stands at the surface or within a few feet of the surface.

Imperfectly developed soils of the former kind are found on alluvial plains of streams, on alluvial fans, on steep slopes where owing to slides, creep and erosion, the soil material has not lain long enough to develop a profile.

In some cases an imperfect profile may be found on a very gentle slope, having formerly been covered by a well developed profile but later subjected to erosion. In such cases the A horizon may be lacking entirely, the B horizon lying on the surface. This kind of imperfect profile should not be confused with one that has never developed or has developed to an imperfect degree. In the latter case the profile will consist mainly of the A and C horizons. The B horizon if present at all will consist of a thin layer of slightly heavier material.

The variations in imperfectly developed profiles may be very great in number. In any given area they should be grouped into alluvial and upland and into a few simple subgroups on the basis of the character of the C horizon in the uplands and in the degree of development of the B horizon. Probably in most regions two main subgroups will be sufficient, one covering cases in which the B horizon has not developed at all and the other cases in which it is present but much thinner than in the well developed soils. Each of these subgroups may be subdivided into minor groups on the basis of differences in the geology of the C horizon.

Alluvial terraces often have soil profiles as well developed as any of the well developed upland soils associated with them. In such cases they will usually differ from other well developed soils only in the character of the C horizon.

Other Developed Profiles

Since we find that one of the universal characteristics of soils on smooth uplands in "humid" regions is a relatively light textured surface or A horizon and a relatively heavy textured deeper or B horizon, it is fair to conclude that one of the processes of development consists in bringing about this difference; in making the surface soil lighter and the layer beneath it heavier in texture.

It is conceivable that the process may in some cases have been extended beyond what may legitimately be called a *well developed difference* and may have developed into what may be called an over developed soil. Such a soil would be characterized by a wide difference in texture between the A

and B horizons. As a matter of fact they are usually marked by an extremely heavy B horizon as well as by a wide difference between the A and B horizons. Such soils should be sought, theoretically, on very smooth areas. Actual experience, shows that they are confined to such areas and are independent of the character of the C horizon.

In regions where lime carbonate has accumulated to a greater or less extent within a depth of 6 feet or less in the soil the general features are somewhat different. This region is usually more or less roughly described as that of deficient rainfall.

The well developed soils of the humid regions as described above the essential features of the soil profile consist of a horizon from which material has been removed, the A horizon; a horizon to which material has been added, the horizon of concentration, the B horizon and a horizon which has not been subjected to any texture change and to no chemical change except at times a certain amount of leaching of the more easily soluble constituents and a certain amount of oxidation.

In the soils of the "dry" regions also the profile of the well developed soil consists of a horizon of chemical extraction, a horizon of chemical concentration and a horizon in which no change whatever has taken place as a rule. In addition to this chemical profile, there is often a texture profile as well but the chemical profile is the one universally present in the well developed soil. The concentration is a concentration of lime carbonate or other salts of the alkalies and alkaline earths. As in the case of the soils within the "humid" region the well developed soil of the "dry" regions is to be found on smooth areas and should be recognized by the presence of a horizon in which lime carbonate is manifestly more abundant than above or below.

In cases where there has developed a well marked textural difference between the surface soil and horizon beneath it the A and B horizons should be defined as in the case of the soils already described. Where there has been no concentration of fine grained material producing a heavy horizon the B horizon may be described as the horizon of salt concentration. (There seems to be no unanimity of practice in the definition of the A and B horizons in the so-called "dry land" soils so for the present we may adopt the plan outlined here).

A wide spread feature of the soils in regions where the rainfall is low is a horizon of loose often sandy material at the surface in the virgin soil. It always has a decided single-grain structure. This is often a mere film in thickness and is probably never more than 3 or 4 inches thick except in places where sand has been accumulated at the surface by wind. Beneath this horizon the material is apt to be much more compact and where exposed in a vertical bank it shows vertical cracks which produce a columnar arrangement. The columns may be large (2 to 5 or 6 inches in diameter) or may be small (an inch or less in diameter). The columns

when dug up carefully and allowed to fall to pieces, without pressure, so that their natural lines of weakness show themselves, will often break horizontally.

The loose surface layer often if not always has a different color from the layer with coarse columns and this is usually different in color from the layer with small columns where both large and small columns are found in the same soil section. (In examining a soil for the presence of columns where observations are made in banks or cuts, a pick or shovel should always be used and the soil should not be wet. The pick should have one broad blade, 3 to 4 inches. This should be driven into the soil hard enough for it to extend to a depth of not less than 5 inches. With the handle as a lever as large a mass of soil as possible should be pried out. If the grass cover be dense it may be necessary to cut it around the block to be lifted. Note whether the soil falls into small or large granules, into small or large columns or into clods of irregular shape. Note whether the columns are granular in structure throughout or only in part, or not at all or whether the highly granular layer falls into granules rather than into columns. Such examinations of the surface 5 or 6 inches are easily made and can be made frequently but they must be supplemented by examinations of the deeper horizons.)

In cases where the soil section has a layer of very heavy material it will usually be found that this layer will assume one or the other of two facies when it is exposed in a cut and has been exposed for a few years. (1) It will crack very irregularly on the surface. The cracks will extend to a depth of an inch or more but it will not break up into a series of angular blocks. (2) The layer on an outcrop will break up into small angular blocks.

In many parts of the United States where the rainfall is very low the soil section or profile consists of a surface crust of less than an inch in thickness, underlaid by a layer of loose but granular material from a film to a thickness of 3 or 4 inches. This in turn is underlaid by a compact layer that may or may not break into columns. Beneath this horizon the section often shows irregular coloration due to imperfect drainage.

Another widely prevalent profile in regions having very low rainfall consists of:

1. A gravel layer, usually called the desert pavement (it may or may not be present).

2. A light colored vesicular layer ranging up to 2 or 3 inches in thickness. The vesicles vary in size from pinhead to a quarter inch in diameter or more in extreme cases. The material collapses very readily into a grayish loose mass with single-grain structure.

3. Usually a loose layer without marked structure features, ranging up to 6 inches in thickness.

4. A compact layer, usually reddish in color, often quite hard. May be

taken out in large blocks (1 ft.). This may be vesicular but is not usually so.

5. Loose material that continues down for several feet.

It is desirable to obtain descriptions of as wide a range of soil profiles in these soils as possible. It is suggested that special attention be directed to the *chemical profile* and the *texture profile* both when they are both present in the same soil and also when only one is present in any soil. In all cases the nature of the salts present should be stated where it can be determined.

In addition to the profiles of the well developed soils the profiles of the imperfectly developed soils should be obtained.

SUBCOMMISSION II

SUBCOMMITTEE ON THE GENERAL SOIL MAP OF THE AMERICAS

Outline of a Scheme for the Differentiation of Soils into Mapping Units on a Uniform Basis for All Countries

Dr. C. F. Marbut, Chairman

Introduction

Pedologists seem finally to have reached the conclusion that soils, like all other natural bodies that have ever been studied by mankind, must be approached directly and studied *as soils.* It seems at last to have been agreed by soil students that the soil cannot be studied effectively through any of the means of indirect approach heretofore used such as the geological, climatic or botanical routes. While it is admitted by even the most enthusiastic advocate of the direct method of approach that the sciences mentioned are important factors in the determination of soil characteristics and must be given full consideration in a search for the forces which cause their development, yet a brief consideration of the history of soil investigation will show how ineffective such consideration has been in promoting the increase of real soil knowledge. We have now arrived at a clear understanding of the difference between the accumulation of knowledge regarding soil characteristics on the one hand and the explanation of the origin of those characteristics on the other. The two things are fundamentally different and cannot be substituted, the one for the other.

Whether the advancement of science as a whole, or of a particular branch of science, is best promoted through the formulation of hypotheses by intuition and the use of any knowledge of facts that may be obtained to determine which hypothesis is best, or whether the proper procedure is through the patient accumulation of facts first and the construction of

principles on them as a basis, may well be left for discussion by others. We may rest secure in the certainty that whichever method may be adopted, no definite conclusion capable of commanding the respect of intelligent human beings can be reached without a knowledge of facts. We shall stand on secure ground therefore if we concern ourselves with facts.

General Soil Maps.—We are to concern ourselves with the construction of a general soil map of each of the several countries of the two American Continents. All such maps will necessarily show *soil groups* rather than *soil individuals.* In order to be able to obtain results that are comparable for the various countries the groups must be defined and differentiated on the same bases in each.

In defining groups of plants or of animals the characteristics of mature individuals only are given consideration. The existence of immature or young individuals is recognized in all cases, but immaturity in organic beings, on account of the relatively short lifespan of the individual, is of short duration and can be neglected in grouping.

In the same way the soils of a region or of a country must be separated into groups, each one defined according to the characteristics of the *fully developed, normal* or *mature* soil prevailing in each part of it. It is now fully agreed by all investigators of soils in the field that in every region in which a given climatic and vegetative environment prevails the normal or mature soil characteristics are much alike throughout its extent. Variations that occur are those of detail, so that the student of the region will begin his work by directing his attention mainly to the mature soils for the purpose of determining those features common to all of them. (For a description of the soil profile features to be looked for and determined see below.)

The areas throughout which one group of similar, but not identical profile characteristics will be found to prevail will be large, and in small countries or in individual states of large countries (such as Amazonas, Brazil, Pennsylvania, U. S. A., Ontario, Canada, for example) they will cover the whole country or state.

In every region the well developed soil, the soil that has adjusted itself to its environment and received its impress, will retain the characteristics thus produced, with slow developmental changes only, as long as the environment remains unchanged. Such a soil can be found only on smooth upland where it has lain undisturbed for a long time. It cannot be found on recently deposited alluvial plains, steep hillsides or recent alluvial fan slopes or in places subjected to excessive moisture.

In the practical solution of the question of the characteristics of the normal or mature soil in any region, therefore, the student should confine his studies to smooth well-drained uplands. Flat surfaces, except in regions where the rainfall is very low, are not best for the purpose because

of their usual poor drainage. The normal or well-developed soil is the well-drained, well-aerated, well-oxidized and deeply weathered soil.

The student will give predominant attention also to soils of intermediate texture, since either heavy clays or loose quartz sands do not usually exhibit clearly the features characteristic of the various stages of soil development. Heavy clays will usually exhibit these features better than sands, but their rate of development is very slow and, other things being equal, they will have thinner layers and less conspicuous horizons than sandy loams, loams or silt loams.[1]

The Soil Profile

Soils are best defined and described when this is done in terms of the vertical section of the soil or *the soil profile.* This is an expression connoting the number, character and succession of the several layers of materials encountered in examining a vertical section of the soil from the surface to a depth of several feet, usually somewhat less than ten. The layers are usually called *horizons.*

The student should first find out how many different *kinds* of *mature* profiles are to be found in the region which he is mapping. These will give him the starting points or the skeleton of his soil map.

Kinds of Profiles.—It will simplify the matter and give concreteness also to outline the principal features on the basis of which the main soil groups of the world are defined, so far as our existing knowledge will permit.

As a preliminary to what is to follow it may be said that every mature or well-developed soil consists of two master horizons, the upper of which consists of several subhorizons, these latter constituting what are usually called soil horizons, and in this paper the term *horizon* means these subhorizons of the *master horizon.*

Frosterus has proposed the term *Solum horizon* or merely Solum for the upper of these two master horizons. In the following pages it will be referred to as the Solum.

The lower master horizon consists of the parent rock or parent material of the soil. It may consist of consolidated rock, disintegrated rock or unconsolidated accumulations of any character whatever. It has re-

[1] Sandy loams, loams and silt loams are terms applied to soils with textures intermediate between true sands on the one hand and heavy clays on the other. In a sandy loam 20 to 50 per cent of the mineral particles are finer in grain or smaller than ordinary road dust or silt. The rest of the mineral material consists of particles larger in diameter than road dust. In a loam there is more than 50 per cent of material smaller than ordinary road dust. It cannot contain more than 20 per cent of clay, or mineral particles with a diameter of $\frac{1}{5000}$ millimeter, though it may contain 50 per cent of silt or dust, soil particles ranging between $\frac{1}{20}$ and $\frac{1}{200}$ millimeter in diameter. A silt loam is a soil containing more than 50 per cent of silt and less than 20 per cent of clay. The rest of the material may be coarser.

ceived no other special name than *parent material.* The Solum is the true soil.

The Solum consists of material that is different in texture, structure, color, and composition from the parent material. Originally, i.e., when it was first accumulated, the parent material extended from the surface indefinitely downward. The difference between the present Solum layer and the parent material expresses the changes which have been brought about in the upper part of this original layer in converting it into the Solum. In the following discussion the term horizon refers in all cases, except where otherwise stated, to the sub-horizons of the Solum.

Profiles of mature soils, throughout the world so far as our knowledge at present will permit us to generalize, consist of two main horizons (1) an upper horizon from which material has been removed, as compared with the lower, a horizon therefore of extraction, and (2) a lower horizon to which material has been added, a horizon of concentration.

In some cases the extraction and concentration have been brought about through mechanical transfer of material, in others, by transfer through solution and reprecipitation (chemically), and in still others by both processes.

Two Main World-Groups of Soils.—There are in general two main soil groups in the world, distinguished one from the other by the prevailing character of the material accumulated in the concentrated horizon.

Group I.—Group I consists of soils in which a mechanical transfer of fine-grained mineral material, clay and silt, from the upper part of the soil to the lower part has taken place, producing a relatively light textured surface soil and a relatively heavy textured subsoil. Along with the mechanical transfer of material there has been some chemical transfer also, consisting of a removal of sesquioxides, alkalies and alkaline earths and organic matter. The percentage of both iron and alumina are relatively low in the light-textured surface layer of soils in this group. How much of such transfer as has taken place is due to the removal of fine-grained material mechanically and how much is due to chemical removal need not be discussed here. It is evident that in most cases chemical action has taken place.

It is usually supposed also that alkalies and alkaline earths have been removed by chemical action from the surface horizon, and the removal of organic matter by this means, in some of the subgroups of this main group, is known to take place. Not necessarily all the material, either that removed mechanically or that removed chemically from the horizon of extraction, becomes concentrated in the horizon of accumulation. In all cases, in the soils of this group all carbonates originally present in the material from which the soil was developed have been removed from both the upper horizon and the horizon of concentration and in many cases the removal of carbonates has extended into the horizon beneath both of

these. Stated briefly, none of the soils in this group contain any carbonates in any of the horizons of the Solum after the soil has become mature or fully developed.

The horizon of extraction, especially the relatively light textured upper horizon, is usually called the A horizon, and the horizon of concentration, the relatively heavy horizon, is called the B horizon, while the material below, in which there has been no noticeable removal or accumulation, is called the C horizon. The latter is the original geological material that has suffered no change except such as has accompanied disintegration and decomposition, if the rocks were originally consolidated, and leaching of carbonates and some other constituents. It is the horizon in which the processes of weathering have not caused concentration of any kind by transfer from overlying horizons. No differentiation into textural horizons has been produced in it through soil-making processes, such variations of this kind as may be found in any particular place being due to original geological conditions.

The horizons most noticeable in the soils of Group I are those due to differences in texture.

The soils of Group I are those developed under conditions of predominant downward movement of moisture sufficient in amount to maintain a permanent moist condition of the soil and parent material down to the permanent water table. They are often called "humid" soils.

Group II.—Group II consists of soils in which a mechanical transfer of fine-grained material from the upper part of the soil and its accumulation in the lower, may or may not have taken place, but in which, in the maturely or fully-developed soil, a layer of alkali or alkaline earth salts, usually lime carbonate, has accumulated in some horizon, which will be called the B horizon. This is the horizon of concentration and in this the concentration is mainly chemical.

The soils of Group II have been developed under conditions of a moisture supply insufficient to maintain a continuous downward movement of moisture to an indefinite depth. They are often called "arid" and "semiarid" soils.

So far as is now known the soils of any part of the world may be grouped into one or the other of these two groups. It will be noted that the grouping is wholly independent of geology, climate, agriculture, native vegetation or geography. It is based entirely on the characteristics of the horizons in the Solum.

Subgrouping of Groups I and II

Each of these two main groups may be subdivided into subgroups. So far as is now known there are five somewhat imperfectly defined but rather distinct subgroups in Group I. They differ one from the other, in the kind of material accumulated in the B horizon, and also in the

degree or extent to which the sesquioxides and alkali and alkaline earth bases have been removed from the soil profile.

Subgroup Ia.—The soils of Subgroup Ia, where not cultivated, usually have an accumulated layer of forest debris, with more or less moss, ranging up to a foot in thickness, though often a good deal less, not well decomposed, always brown rather than black in color, and acid in its reaction. It is underlaid by the mineral soil, always gray in color, often strikingly so. This layer ranges up to more than a foot in thickness, though, except in very sandy soils, it is usually less than 8 inches.

The third layer or horizon is brown, yellowish brown, or coffee brown in color and may assume a wide range of conditions as to induration. It may be loose with a decided "velvety" feel, it may be indurated to a stonelike condition, or it may have any intermediate condition. Where indurated the color is usually darker than where soft. Induration seems to be more common in sandy than in heavy soils. Chemically it contains a relatively high percentage of organic matter, and of iron or alumina, or both, while the gray layer has a lower percentage of all these constituents and a higher percentage of silica. The color of this brown or B horizon is strongest at the top. It grades with depth imperceptibly into the parent geological material, whatever that may be. Since the soils of this subgroup occur in cool humid regions the parent material is likely to consist of glacial till, but this is not always true.

In making a general soil map of a region in which these soils (the Podsols) prevail many subdivisions may be made on the variations in the thickness of the A or B horizons on variations in the character of the parent geological material found in the C horizon.

In a general map calcareous and non-calcareous glacial drift should be separated, soils with loose sand and gravel parent material separated from those with clay parent material, and other subdivisions made on the basis of important rock differences. The most important distinction that can be made, it should be remembered, is between calcareous and non-calcareous parent material.

Subgroup Ib.—Another subgroup consists in the virgin soil of a surface cover of leaves and leaf mold, usually thin. The leaf mold is rarely more than an inch thick, is dark to black, well decomposed, and usually granular in structure. It is often mixed with some mineral soil.

The top layer of the mineral soil, 1 to 4 or 5 inches in thickness, is darkened by some admixture of organic matter, but below this it is light brown to yellowish brown in color. These layers constitute the A horizon, the whole thickness of which ranges up to about 18 inches.

The B horizon is heavier than the A, as is true of all soils of this main group, and is a deeper brown in color. It may be pale reddish in color. It has no coffee-brown organic accumulation and the A horizon is never as gray as in the previous group. The B horizon has a higher percentage

of alumina and iron oxide and the A horizon is relatively high in silica. Neither has any lime carbonate, but in the loams, sandy loams, silts, and clays the potash percentage is usually rather high. The organic matter in the A horizon is generally low and under cultivation it disappears rapidly. These soils are developed in regions similar to France, Southern Germany, and the midlatitudes of the United States. Subdivisions in mapping within the regions where soils of this subgroup are predominant will be based on the geological character of the C horizon and variations in details of the other horizons. This subgroup is usually called the Brown Soil Group.

Subgroup Ic.—A third subgroup consists of a surface soil or A horizon much like that of the Brown soils. It is somewhat more yellow and more thoroughly decomposed and contains, apparently, when soils of equivalent textures are compared, a higher percentage of colloids than the soils of the Brown group, is more thoroughly leached of bases throughout the whole profile, and contains a higher accumulation of sesquioxides.

These soils are found in the southeastern part of the United States, seem not to be found in Europe, but will probably be found in large areas in southern Brazil. Their distinguishing characteristics are: low organic matter, low alkalies and alkaline earths, gray to yellow color of A horizon, yellow to red color of B horizon, and high concentration of sesquioxides in B horizon. They are usually designated as the Yellow and Red Soil Group.

Subdivisions into smaller mapping units will be based on details of profile and on character of the parent geological material.

Subgroup Id.—A fourth group consists of yellowish and reddish to red soils not differing essentially in this respect from the previously described group. They have light-colored and light-textured A horizons and heavier textured B horizons in which there is strong accumulation of ironoxide and alumina and strong leaching of the alkali and alkaline earth bases. In all these respects they are very much like the previously described group, but the leaching of bases and accumulation of sesquioxides has gone further. These are mere differences in degree and not in kind.

There is one respect however in which there seems to be a difference, though this is offered tentatively. This consists of a zone of segregation of hydrated iron oxide. There is the usual accumulation of hydrated iron oxide in the B horizon, seemingly in the colloidal state, and, in addition, a segregation of iron oxide that may be very large in quantity. This seems to take place at the base of or in the lower part of the B horizon and the upper part of the C horizon, beginning seemingly as a segregation in spots or streaks. These increase in size and numbers until a zone or layer ranging up to several feet (10 ft. ±) in thickness has become a network of such streaks with white or light-colored material filling the intervening meshes. On outcrop or where brought near the surface by erosion

of the overlying material this network becomes indurated, and if exposed the white mesh-filling clay will be washed out and the iron-oxide mass will become slaglike; or it may break up into fragments. When not exposed or brought near the surface this mass does not seem to indurate.

It is possible also that accumulations of aluminum hydroxide will be found in similar positions, but at present the iron oxide (hydroxide) accumulation is the only one that is known to have wide distribution.

These iron oxide accumulations are known rather widely in tropical regions as laterite. The soil student is not interested in them as such but is interested in soils of which they form a horizon. We may term such soils lateritic. It is desirable to obtain information as to their extent. Like the soils of the other groups, they may be subdivided on the basis of details of the profile and differences in the character of the C horizon.

Subgroup Ie.—A fifth and last subgroup of Group I is closely related to the second subgroup (Ib) differing from it mainly in the color of the upper part of the A horizon. In the virgin condition it is not covered with a layer of leaf mold. The layer of dark-colored mineral soil that in the second subgroup is very thin reaches a thickness in this ranging from 6 inches to a foot or more. In the rest of the profile its features are very much like those of the second subgroup. The high percentage of organic matter in the surface soil has brought about some changes in the B horizon, especially in those cases where all the soil horizons are rather heavy and the B horizon becomes a clay. In drying the soil cracks to great depths and dark-colored soil from the surface falls into the cracks. This causes a streaking of the B horizon with dark-colored material and gives it also a higher percentage of organic matter than the B horizon of subgroup Ib.

Subdivision into smaller groups for mapping may be based on differences in detail of the profile and in the character of the parent geological material constituting the C horizon. The foregoing five groups cover those subgroups of Group I which have been defined with sufficient clearness for field identification.

Subgroups of Group II.—The subgroups of Group II seem to be somewhat less well defined but about eight subgroups may be defined with sufficient clearness to make identification in the field possible.

It will be borne in mind that the one characteristic common to all the mature or well-developed soils of Group II is the presence in the subsoil, the B horizon, of lime carbonate, more or less accumulated and present in a higher percentage than in the unmodified geological material below. Associated soils not having such layers or horizons of accumulation, are immature.

Subgroup IIa.—The surface soils of the members of this group are black, very dark brown, or very dark gray-brown, and the dark-colored layer is as a whole thicker and darker than this layer in any other group

of soils. The lower part of the A horizon may or may not be brown. The upper part of the B horizon is brown to yellow-brown, heavier as a rule than the A horizon, may be much heavier, and may or may not contain lime carbonate. The lower part of the B horizon is highly calcareous. The C horizon may consist of any kind of material except pure quartz sand, and the subdivision of the group for mapping purposes is based on details of the profile of the Solum horizon and the character of the parent geological material.

Subgroup IIb.—This may be considered a phase of subgroup IIa, though it will be given independent recognition here. The soils in it differ from those in subgroup IIa in having a very dark brown or dark reddish brown surface soil and a reddish to red horizon between the dark-colored surface horizon and the layer with high content of lime carbonate. The latter is often pinkish in color, is highly concentrated, and may be indurated to a limestone.

Subdivisions may be made on the same bases as in other subgroups.

Subgroup IIc.—The surface soil is dark brown. It is thinner than in subgroup IIa. The layer beneath the dark-colored horizon is brown or yellowish and the heavier or B horizon is brown. In some cases it is but little heavier than the A horizon. The layer with high lime content lies at shallower depth than in subgroup II a. Subdivide as in other subgroups.

A *variety* or phase of this subgroup is found in many regions which has a very thin loose surface layer of an inch or two and a compact dark-colored layer beneath it which in exposed banks breaks into columns.

Subgroup IId.—This has the same relation to subgroup IIc as subgroup II b has to subgroup II a. The color of the A horizon is less dark, the material between this and the lime horizon is often reddish, and the lime horizon may be indurated to a limestone or *caliche.* Subdivide on usual basis.

Subgroup IIe.—The soils of this subgroup differ from those of subgroup IId in a lighter colored surface or A horizon and a still shallower lime horizon. The A horizon is brown to slightly dark brown. The lime horizon is often found within a foot of the surface. Subdivide on usual basis.

Subgroup IIf.—These soils have the same relation to those of subgroup IIe as the soils of subgroup IId have to those of subgroup IIc. (Less dark, reddish and indurated lime carbonate zone.) Subdivide on usual basis.

Subgroup IIg.—The soils of subgroup IIg are gray, the lime zone in the heavier members is often on the surface or near it. These are true desert soils.

Subgroup IIh.—The soils of this subgroup are merely reddish members of subgroup IIg. They lie,.as in the case with the reddish subgroups already listed, in regions with high annual temperatures.

Soils with Imperfectly Developed Profiles

In smooth or gently undulating or rolling uplands, where surface drainage is good to fair and the ground-water table stands several feet below the surface, soils with imperfectly developed profiles do not cover a large proportion of the total area. They are of relatively little importance.

In many regions, however, soils with imperfectly developed profiles cover considerable areas and therefore assure considerable importance. Such soils are said to be imperfectly developed because of the absence either of a heavier B horizon, a zone of lime carbonate accumulation, a layer of iron oxide accumulation, or because of the lack of good oxidation and drainage in either the A or B horizons. They may also be characterized by the absence of horizons or layers of any kind except those due to the manner of deposition of the material. Such soils may be found in the following situations:

1. Mountainous and hilly regions on slopes so steep that only a thin layer of soil material overlies the rock at any time. It does not lie in place long enough to become differentiated into horizons by weathering.

Differentiate from the mature soil with which it is associated according to color, texture, and character of the geological material.

2. Areas where surface and subsoil drainage are poor and the soil has been subjected to water-logging.

Differentiate according to surface color, texture, or the degree of wetness as shown by degree of deoxidation or lack of oxidation in material below surface.

3. Alluvial plains. Material has been deposited so recently that not sufficient time has elapsed for soil profile to have developed. (Terrace soils are usually mature.)

Differentiate according to color, texture, the character and source of the material, and the perfection of drainage.

Alkali Soils

The term *Alkali*, as used in the United States to designate a group of soils, refers to soils in which there is an accumulation of water-soluble salts in some part of the soil of sufficient concentration to injure growing crop plants or prevent their growth entirely.

They are differentiated according to texture and other features of the profile and according to the character of the salts that have accumulated. Of the latter there are two kinds, "white alkali" and "black alkali." The former consists of chlorides and sulfates while the latter consists of the carbonate of soda.

SUBCOMMISSION III

The International Soil Map of Europe

Dr. H. Stremme, Germany, with the collaboration of Drs. V. Agafonoff, France; J. von Baren, Holland; K. Björlkke, Norway; G. Bontschew, Sofia; N. M. Comber, England; P. Enculescu, Rumania; Fraser, Scotland; B. Frosterus, Finland; G. Georgalas, Greece; K. D. Glinka, Russia; J. Harlissy, Ireland; J. Hendrick, Holland; K. Heykes, Germany; V. Hohenstein, Germany; W. Hollstein, Germany; H. Jenny, Switzerland; G. Krauss, Germany; T. Mieczyński, Poland; S. Miklaszewski, Poland and Lithuania; F. Münichsdorfer, Germany; G. Mürgoci, Rumania; G. Newlands, Scotland; V. Novák, Czechoslovakia; W. Ogg, Scotland; A. Opperman, Denmark; P. Protopopescu, Rumania; G. W. Robinson, Wales; B. Ramsauer, Austria; A. Stebutt, Yugoslavia; O. Tamm, Sweden; A. Till, Germany; P. Trietz, Hungary; E. del Villar, Spain; G. Wiegner, Switzerland; J. Wityn, Latvia and Esthonia; W. Wolff, Germany, prepared the map included in this report.

The detailed reports of some of the contributors that were unable to present their papers in time for publication with the original work are submitted and published here in connection with the report of this subcommission.

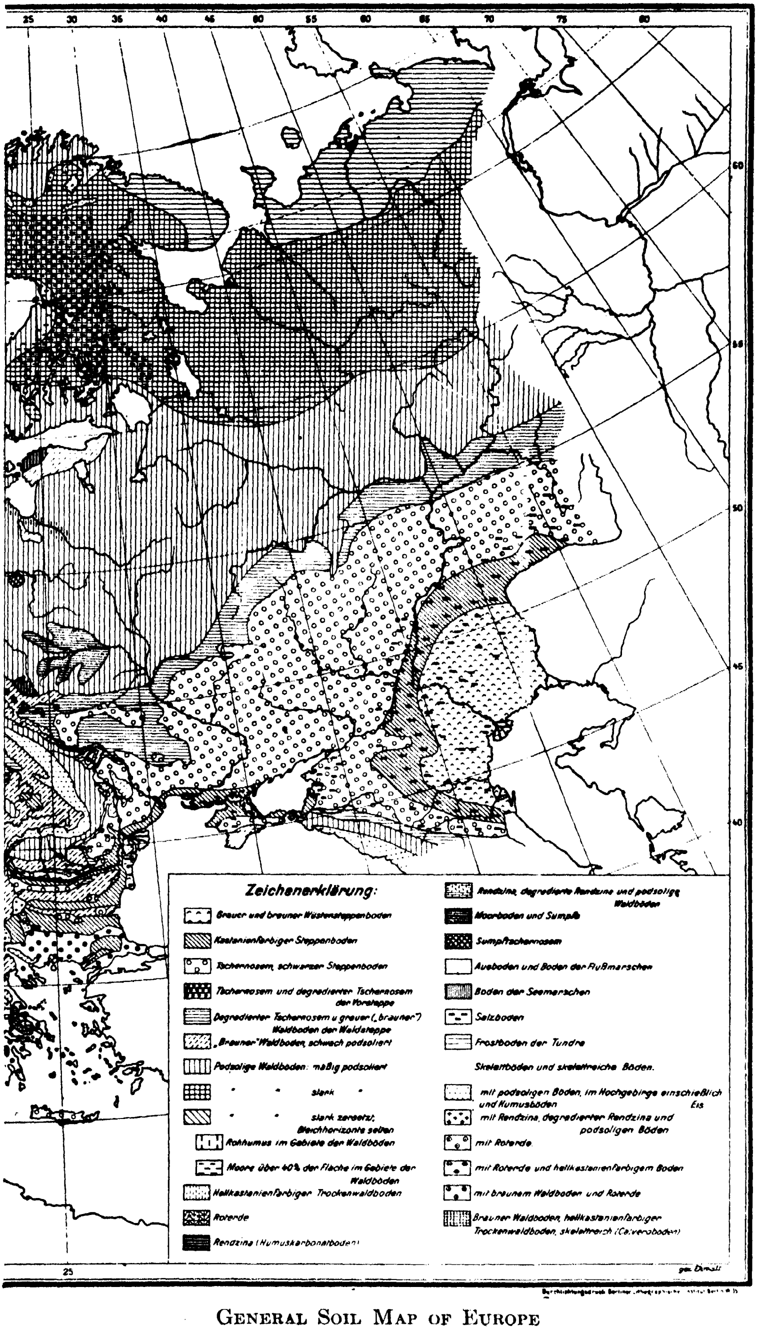
DIE KLIMATISCHEN BODENREGIONEN IN SCHWEDEN

Dr. O. Tamm

Auf dem bodenkundlichen Kongress in Rom, Mai 1924, wurde beschlossen, dass eine Übersichtskarte der klimatischen Bodentypen Europas durch Fachleute der verschiedenen Länder ausgearbeitet werden sollte. Für Schweden wurde Verf. Mitarbeiter. Auf einer Konferenz in Berlin, Mai 1925, wurden die Richtlinien näher diskutiert und bestimmt und darauf in Budapest, August 1926, noch weiter ergänzt. Es ist beschlossen worden, zuerst eine kleine Übersichtskarte im Massstab 1:10,000,000 anzufertigen. Es sollten darauf teils die klimatischen Bodenzonen und Bodenregionen, teils, wenn möglich der Untergrund, also die Geologie, angegeben werden.

Obgleich eine Karte der klimatischen Bodentypen Schwedens bisher noch nicht hergestellt worden ist, sind der Zusammenhang zwischen Klima und Boden sowie Gesichtspunkte für eine Bodenkartierung Schwedens von Hesselman in "État de l'étude et de la cartographie due sol", Bucarest 1924, eingehend behandelt worden. Auch findet man dort Berichte über Arbeiten und Karten der Geologischen Landesanstalt Schwedens (Sveriges Geologiska Undersökning) von den Herren A. Gavelin (Chefdirektor),

General Soil Map of Europe



General Soil Map of Europe

S. Johansson (Staatsgeologe) und L. v. Post (Staatsgeologe). Die quartären Ablagerungen Schwedens werden von der Geologischen Landesanstalt vorzüglich kartiert, auch übersichtliche Zusammenstellungen werden gegeben. Meine hier erscheinende Kartenskizze der Bodentypen-Regionen ist als eine Ergänzung zu den Aufsätzen über Schweden in dem oben zitierten Werk, das unter der Leitung Murgocis in Bucarest veröffentlicht wurde, zu betrachten. Es sei jedoch betont, dass meine Skizze nur den Charakter *einer ersten Orientierung* hat.

A. Der Untergrund der Böden

Es hat sich gezeigt, dass es für Schweden ganz unmöglich ist, in irgend wie befriedigender Weise in so kleinem Massstab wie 1:10,000,000 den Untergrund der Böden, das heisst die Bodenarten (sensu Stremme 1926), kartographisch zum Ausdruck zu bringen. Die Verhältnisse sind zu wechselnd. Dagegen ist es leicht, eine Vor stellung von der Verbreitung der wichtigsten der Bodenarten durch verschiedene vorhandene Übersichtskarten zu erhalten.

Abbildung 1.—Verbreitung von Land und Meer in Fennoskandia und dessen Umgebungen während der Abschmelzung des letzten Landeises. Die dicht punktierten Gebiete waren meerbedeckt; das schwach punktierte im Süden war Früher Land. (Aus A. G. Högbom: Fennoskandia, Handbuch der regionalen Geologie IV: 3)

Die Bodenarten Schwedens sind fast ausschliesslich spätquartären Alters, d.h. sie stammen von der letzten Vereisung oder aus der postglazialen Periode her. Die postglazialen Bodenarten bestehen, wenn sie nicht organogenen Ursprungs sind, meistens aus umgelagertem Material der spätglazialen Bildungen. Die Zeit, die verflossen ist, seitdem das letzte Inlandeis anfing vom südlichsten Schweden abzuschmelzen, beträgt nach den bekannten Bestimmungen von De Geer und Mitarbeitern (siehe De Geer 1925) 14,000–16,000 Jahre. Aus Nordschweden zog sich das Inlandeis vor etwa 8,000–9,000 Jahren zurück.

Die glazialen Ablagerungen entstanden fast ausschliesslich durch mechanische Zertrümmerung und Abnutzung der Verschiedenen präglazialen Gesteine meist archäischen Ursprungs: Granite, Gneise, Porphyre und andere. Ausser den archäischen Gebieten gibt es die grosse Hochgebirgsregion in Nordschweden längs der norwegischen Grenze hauptsäch-

ABBILDUNG 2.—Schweden 1:10,000,000. *Schwarz:* Kalkführende, nicht metamorphosierte, feste Sedimentgesteine. *Gestrichelt:* Kalksteinsmaterial enthaltende Bodenarten

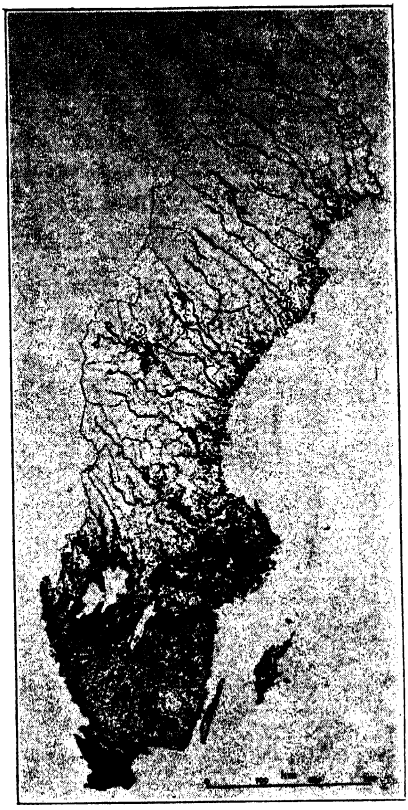


ABBILDUNG 3.—Schweden 1:10,000,000. Die Verteilung der Ackerböden in Schweden. *Schwarz:* Ackerboden. *Weiss:* Ausser der Hochgebirgsregion hauptsächlich Waldböden, aber mit zerstreuten Kahlfelsen, sowie Moore und Seen. (Aus *Anrick:* Ny karta över sveriges åkerareal, Ymer 1919). Die Karte, verglichen mit Abb. 2 und 3, zeigt sehr gut, wie der ackerbau besonders die Gegenden der kalkfuhrenden Sedimentgesteine und die unter der Grenze des spätglazialen Meers vorkommenden Lehme und Tonen in Anspruch genommen hat. Die Hochgebirgsregion: siehe die Bodenregionen-Karte

lich mit kambrisch-silurischen, metamorphen Sedimentgesteinen und eine Anzahl kleinerer, zerstreuter Flächen mit normalen Sedimentgesteinen von postarchälischem und zwar präkambrischem, kambrisch-silurischem und mesozoischem Alter. Die Bodenarten bestehen somit aus chemisch fast unverwitterten Gemischen von Material aus den genannten, festen Gesteinen; nur die kleinsten Körner, die Tonpartikeln, zeigen eine Zusammensetzung, die auf chemische Verwitterung während der spätglazialen Zeit hindeutet (Tamm 1920, 1925).

Die grösste Verbreitung unter den Bodenarten Schwedens zeigen die sandig-lehmigen, Steinschutt enthaltenden, aus Granit, Gneisen und ähnlichen Gesteinen gebildeten Moränen. In dem Teil des Landes, der über der Grenze des spätglazialen Meeres liegt, sind solche Moränen im allgemeinen vorherrschend. Hier und da kommen jedoch auch Kies und Sand glaziofluvialen Ursprungs vor. Unter der Grenze des spätglazialen Meeres (siehe Abbildung 1) finden sich grosse Flächen mit Lehmen und

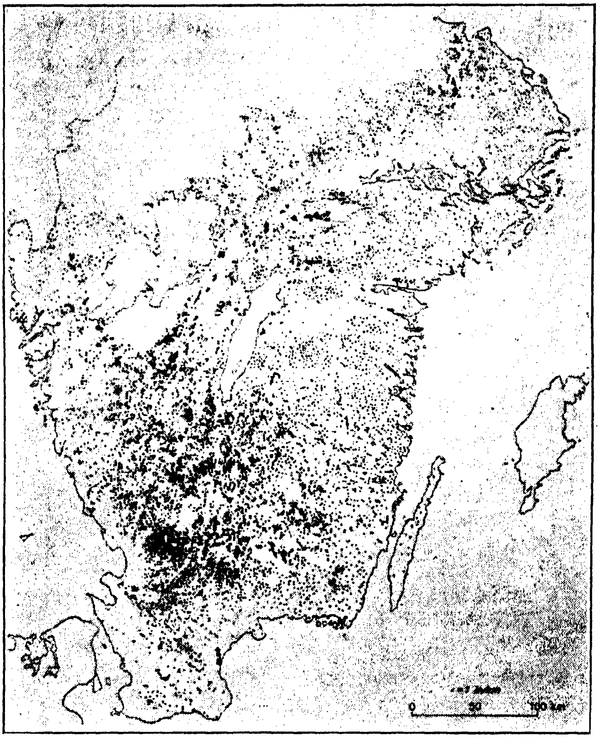


ABBILDUNG 4.—Die Torfböden in Süd- und Mittelschweden. *Schwarz:* Torf. (Aus L. v. Post: Södra Sveriges Torftillgångar. Sveriges Geologiska Undersökning. Årsbok 19, 1925)

Tonen. Diese Sedimente decken jedoch nie das ganze Areal des Gebietes, sondern es kommen immer auch normale Moränen sowie Moränen, die durch das Spülen der Meereswellen in Sand oder Kies umgewandelt worden sind, glaziofluviale Sande und Kiese und auch nackte Felsböden vor. Da die Lehme und Tone für den Ackerbau sehr geeignet sind, findet man unsere Ackerbaudistrikte besonders in den Teilen des Landes, die unter dieser Meeresgrenze liegen. In Kalkstein- und Schiefergebieten (siehe Abbildung 2) sind die Moränen selbst sehr lehmig und arm an Steinschutt und spielen somit gleichfalls eine wichtige Rolle für den

Ackerbau. Abbildung 3 zeigt die Verbreitung der Ackerböden in Schweden. Was nicht beackert ist, ist ausser den Hochgebirgen (vgl. die Karte der Bodentypen) zum grössten Teil bewaldet. Jedoch sind darin bedeutende Areale von nackten Felsböden und waldlosen Mooren sowie kleine Seen eingeschlossen.

TABELLE 1.—Mittlere Lufttemperatur in Schweden 1859–1925. (Von der meteorologisch-hydrographischen Anstalt mitgeteilt.) Die verschiedene meteorologische Stationen sind in Gruppen nach der Bodenregionen eingeteilt.

	Lat. N	Long. E Gr.	Höhe ü.M.n.	Januar	April	Juli	Oktober	Jahr
Region 2, nördlicher Teil.			m.					
Karesuando	68° 27′	22° 30′	333	−14,6	−4,6	+12,5	−2,7	−2,7
Gällivare	67° 8′	20° 40′	365	−13,0	−2,1	+13,9	−1,6	−1,1
Jokkmokk	66° 36′	19° 51′	255	−14,5	−1,3	+14,4	−1,2	−1,0
Stensele	65° 4′	17° 10′	328	−12,1	−0,8	+13,9	+0,2	−0,1
Haparanda	65° 50′	24° 9′	9	−11,0	−1,7	+15,1	+1,4	+0,6
Umeå	63° 50′	20° 17′	17	− 8,1	+0,1	+15,0	+2,7	+2,1
Östersund	63° 11′	14° 39′	331	− 8,4	+0,8	+13,9	+2,7	+2,0
Härnösand	62° 38′	17° 57′	9	− 6,3	+1,3	+15,3	+4,2	+3,4
Särna	61° 41′	13° 7′	453	−11,7	+0,4	+13,8	+1,4	+0,8
Falun	60° 37′	15° 38′	122	− 6,0	+2,6	+16,4	+4,5	+4,3
Region 2, Südwestlicher Teil.								
Göteborg	57° 42′	11° 58′	17	− 0,5	+5,5	+16,9	+8,0	+7,4
Ulricehamn	57° 48′	13° 25′	270	− 3,4	+3,3	+15,2	+5,3	+5,0
Halmstad	56° 40′	12° 52′	10	− 0,8	+5,4	+16,9	+8,0	+7,4
Region 3.								
Gävle	60° 40′	17° 9′	21	− 4,3	+2,6	+15,9	+4,9	+4,6
Uppsala	59° 51′	17° 38′	24	− 4,1	+3,0	+16,5	+5,1	+4,9
Västerås	59° 37′	16° 33′	18	− 3,7	+3,5	+17,0	+5,6	+5,4
Karlstad	59° 23′	13° 30′	53	− 3,3	+3,8	+17,2	+6,1	+5,8
Stockholm	59° 21′	18° 4′	44	− 2,9	+3,3	+16,8	+6,3	+5,7
Linköping	58° 25′	15° 38′	64	− 2,4	+4,3	+17,1	+6,4	+6,2
Jönköping	57° 47′	14° 10′	98	− 1,8	+3,8	+16,1	+6,7	+6,1
Västervik	57° 47′	16° 36′	12	− 1,6	+4,0	+16,7	+7,1	+6,5
Region 4.								
Visby	57° 39′	18° 18′	11	− 0,4	+3,7	+16,1	+7,8	+6,7
Kalmar	56° 40′	16° 22′	10	− 1,0	+4,3	+16,9	+7,9	+6,9
Växjö	56° 53′	14° 49′	173	− 2,4	+4,3	+16,3	+6,4	+6,1
Lund	55° 42′	13° 12′	38	− 0,8	+5,2	+16,5	+8,0	+7,2
Ystad	55° 26′	13° 50′	5	+ 0,1	+5,0	+16,1	+8,9	+7,4

Ausser den erwähnten Ablagerungen bildet auch der Torf eine Hauptbodenart in Schweden. Er kommt in allen Teilen des Landes in grosseren oder kleineren Torfmooren vor und deckt in vielen Gebieten mehr als 20% der Landesoberfläche. Für Süd- und Mittelschweden hat L. v. Post (1926) eine Übersichtskarte der Torfbildungen (Mooren) veröffentlicht (siehe Abbildung 4). Gegen Norden nimmt der von Torf bedeckte Prozentsatz der Landesfläche im allgemeinen zu. In der Abhandlung v. Post's findet man sehr eingehende Untersuchungen über Torf und Torfböden in Süd- und Mittelschweden mit einer grossen Anzahl von Karten.

B. Das Klima

Das Klima Schwedens ist durch den warmen Golfstrom beeinflusst und muss daher als sehr mild angesehen werden, wenn man die hohe geographische Breite berücksichtigt. Es steht zwischen dem ausgesprochenen ozeanischen Klima der Küstengegenden des Atlantischen Meeres und dem kontinentalen Klima Russlands. Auch zwischen Ostschweden und West-schweden treten sehr merkbare Unterschiede, z.B. in den Niederschlägen, hervor. Wegen der sehr grossen Ausdehnung des Landes in nord-südlicher Richtung sind die Unterschiede der mittleren Temperatur in Nordschweden und Südschweden sehr gross. Tabelle 1 zeigt die Temperaturverhältnisse verschiedener Teile Schwedens. Abbildung 5 gibt die mittlere Niederschlagsmenge an.

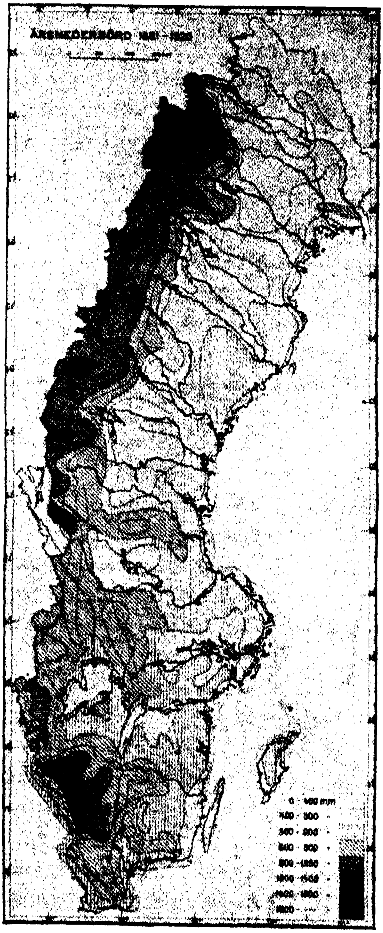


Abbildung 5.—Jährliche Niederschlagsmenge in Schweden 1881–1920. 1:10,000,000. Mitgeteilt von Statens Meteorologisk-Hydrografiska Anstalt

C. Die klimatischen Bodentypen und Bodenregionen

Bis jetzt sind in Schweden nur die Waldböden vom Standpunkt der klimatologischen Bodentypen aus untersucht worden. Da man in jedem Teil des Landes ausser den Hochgebirgen Waldböden findet (vgl. Abbildung 3), die nie vom Pfluge berührt worden sind, kann man durch Waldbodenuntersuchungen *die wahren natürlichen Bodenregionen* studieren. Inwieweit die natürlichen Böden durch den Ackerbau verändert worden sind, ist bisher nicht genügend untersucht worden.

Beim Untersuchen der Waldböden findet man sogleich, dass die Eigenschaften der Humusformen der obersten Schichten im Bodenprofil von sehr grosser Bedeutung sind. P. E. Müller (1887) hat bei seinen schönen Untersuchungen über die Wald-und Heideböden Dänemarks dies für die dänischen Verhältnisse klargelegt. Seine Schlüsse gelten,

wiewohl in gewissen Hinsichten modifiziert, auch für Schweden. Neuerdings hat Hesselman (1926) die Humusfragen wieder eingehend behandelt. Die Bedeutung der Humusformen ist, nach den erwähnten Autoren, zwiefach. Erstens ist die Humusform in höchstem Masse für die Eigenschaften des Bodens bezeichnend, wenn es auf waldbauliche Ausnützung ankommt, z. B. bei der Verjüngung des Waldes u.s.w. Zweitens ist die Humusform ein Austruck verschiedener Faktoren, die die ganze Bodenbildung hervorrufen. Die Humusform ist, mehr als andere Bodenbestandteile, das Werkzeug des Klimas und der vom Klima in erster Linie abhängigen Vegetation bei der Ausbildung des Bodenprofils. Die Unterschied der Humusformen unserer natürlichen Böden geben in vielen, sehr wichtigen Hinsichten die Unterschiede der Böden vom praktischökonomischen Gesichtspunkt an. Es ist darum der Humusform bei der Einteilung der Bodentypen ein grosser Wert beizumessen.

Unter Berücksichtigung der Entwicklung der Bodenforschung in Dänemark und Deutschland hat Hesselman (1926) folgende Definitionen von den Humusformen der nicht versumpften Böden gegeben:

Rohhumus: Durch Pilzhyphen, Myzelfäden oder höhere Pflanzenwurzeln filzartig zusammengewobene Humusdecke, die von der Mineralerde deutlich getrennt ist.

"Mor": Lockere, durch Pilzhyphen wenig zusammengewobene Humusdecke, nur wenig mit Mineralerde vermischt.

Mull: Humusschicht meistens mit viel Mineralerde vermischt, von ausgeprägter Krümelstruktur.

"Mor" steht zwischen Rohhumus und Mull. Ubergänge zwischen den verschiedenen Humusformen kommen oft vor.—An die erwähnten Humusformen reiht sich der *Torf*, der in den versumpften Böden vorkommt. Oft bildet er mächtige Lager, die in Mooren als eine selbständige Bodenart angesehen werden müssen, aber er kommt auch in dünnen Schichten, z. B. 2–5 Dezimeter dick, als Humusdecke in Bodenprofilen vor. Die Bildung des Torfes ist immer durch übermässige Befeuchtung bedingt und ist eine lokale Erscheinung. Übergänge zwischen Torf und Rohhumus und auch zwischen Torf und Mull kommen natürlich an den Grenzen der von Grundwasser beeinflussten Böden vor.

Als natürliche klimatische Bodentypen wollen wir solche Bodentypen bezeichnen, die ohne irgend einen örtlichen Einfluss (z. B. Süd-Exposition, hohen Grundwasserstand u.s.w.) durch die vom Klima bedingten natürlichen Pflanzenvereine gebildet sind. Der Haupttypus des ganzen Landes ist der Auslaugungsboden oder der Podsol, aber es gibt eine Reihe verschiedener Untertypen, von den sehr schwach (oder nicht merkbar) podsoligen *braunen Laubwaldböden* im Süden bis zu den ausgesprochenen *Rohhumuspodsolen* im Norden und Westen. Eine Zwischenstellung nehmen die Podsole mit Mull oder Mor ein. In der Hochgebirgsregion in Nordwest-Schweden ist der klimatische Bodentypus ein Frostverwitter-

ung-S-Boden (Skelettboden). Ausser den erwähnten Typen kommen wichtige Ortsböden vor, unter denen vor allem die—Humuspodsole, echte Grundwasserböden (Frosterus 1914) und Moorböden—eine grosse Rolle spielen. In fast allen Teilen des Landes, auch in Ebenen, kommen Felsböden vor, wo die Verwitterung noch nicht Zeit gehabt hat, einen wirklichen Bodentypus zu schaffen.

Wegen der in Schweden meistens sehr kleinhügeligen Landschaft kommen immer verschiedene Bodentypen zu Folge örtlicher Einflüsse zur Ausbildung. Man hat im allgemeinen ein Mosaik von verschiedenen Typen, unter denen man jedoch, obgleich nicht ohne Schwierigkeiten, den klimatischen Typus erkennt. Es ist darum sehr schwer, die Grenzen zwischen den vorhanden Bodenregionen genau zu ziehen. Die jetzt vorliegenden Untersuchungen und Profilaufnahmen in den verschiedenen Teilen des Landes haben sicher verschiedene Regionen mit verschiedenen charakterisierenden Bodentypen aufgezeigt, und diese Regionen sind eng mit den pflanzengeographischen Verhältnissen verknüpft. Um die Grenzen zwischen den verschiedenen Regionen ziehen zu können, müssen wir zurzeit meistens gewisse wichtige pflanzengeographische Linien zu Hilfe nehmen und begehen wahrscheinlich dabei nicht allzu grosse Fehler. Sobald mehr Bodenaufnahmen für unser sehr ausgedehntes Land vorliegen, können die Grenzen korrigiert werden; die hier gegebene Karte (Abbildung 6)[1] darf nur als ein erster, skizzenhafter Versuch angesehen werden. Die Grenzlinien Sollten eigentlich als *Grenzstreifen* bezeichnet werden.

1. *Die Region der mechanischen Verwitterung = die Hochgebirgsregion*

Arktisches Klima, meistens mit reichlichen Niederschlägen. Diese Region ist nach unten durch die Waldgrenze (Birkenwald) abgegrenzt. In den Hochgebirgen sind die Böden durch mechanische Verwitterung (durch Frost) und durch häufiges Erdfliessen gekennzeichnet. Hierdurch erklärt sich, warum man sehr oft kein charakteristisches Bodenprofil antrifft. Wo die Vegetation einen geschlossenen Teppich bildet, findet man jedoch Podsolprofile, und zwar meistens Humuspodsol mit torfiger Humusdecke. Auch Übergänge zwischen Humuspodsol und Eisenpodsol mit Rohhumus, also Rohhumuspodsole (Eisenpodsol, Frosterus (1914, 1924)) kommen vor. Alle diese Podsole finden sich eigentlich nur in den niedrigeren Teilen der Region.

2. *Die Region des Rohhumuspodsols*

Diese Region zerfällt in zwei etwas verschiedene Gebiete, wo verschiedene Klimafaktoren eine ausgeprägte Rohhumusbildung hervorrufen.

[1] The editor is unable to reproduce this map as it was misplaced. It was, however, used in the preparation of the General Soil Map of Europe by Dr. Stremme, see page 270.

Das eine wollen wir das nördliche, das andere das südwestliche nennen. Die Grenze zwischen ihnen muss zurzeit etwas willkürlich gezogen werden.

a. *Das nördliche Gebiet. Niedrige mittlere Temperatur, wenig Niederschläge.*—Nach unten von der Birkenwaldgrenze kommt die Region des Rohhumuspodsols. Als Grenze gegen Region 3 ist in der Hauptsache die Nordgrenze der Eiche gewählt, also die Nordgrenze des Vorkommens von sommer-grünen Laubwäldern von mitteleuropäischem Typus.[1] Die Rohhumuspodsole sind im ganzen Gebiet vorherrschend. Die Vegetation ist meistens Nadelwälder, oft mit etwas Birken, Espen, Erlen und Salices vermischt. Längs der Grenze an der Hochgebirgsregion gibt es reine Birkenwälder. Die Rohhumuspodsole sind dadurch gekennzeichnet, dass der A-Horizont in eine scharf ausgeprägte Rohhumusschicht und eine grauweisse, sehr humusarme Bleicherdeschicht geteilt ist. Die Orterde ist durch Eisenverbindungen meistens rostrot oder rostgelb gefärbt, zuweilen, besonders oft in den nördlichsten Teilen der Region, ist sie als Eisenortstein ausgebildet. Dieser Ortstein deckt nie grosse Areale und kommt im allgemeinen nur fleckenweise vor. Die Dicke der Rohhumusschicht wechselt. In den Fichtenwäldern ist sie am dicksten, oft 10–15 cm. oder an einzelnen Punkten noch mehr. In den sogenannten Kiefernheiden, wo der Wald mehrmals abgebrannt ist, ist der Rohhumus meistens sehr dünn. Diese Böden entwickeln sich im allgemeinen langsam in der Richtung gegen "Fichtenwaldpodsole," wenn keine Waldbrände mehr stattfinden.

Auf ziemlich schweren Tonen in den Küstengegenden (die vom Meer bedeckt waren siehe Abbildung 1) ist die Podsolierung ganz schwach, oft kaum merkbar. Das kommt offenbar daher, dass die bodenbildenden Prozesse in dem kühlen Klima der Region während der verhältnismässig kurzen Zeit seit dem Abschmelzen des Inlandeises und dem Aufsteigen der Landfläche über das Meeresniveau noch nicht Zeit genug gehabt haben, die Tone in deutliche Podsolböden umzuwandeln. Man findet eine Rohhumusdecke auf dem Ton, der in den oberen Schichten etwas gelockert worden ist; wo der Ton etwas lehmig-sandig ist, findet sich auch eine deutliche Bleicherde und Orterde.

Neben dem normalen Podsolprofil, der unbedingt der klimatische Typus ist, spielt der *Humuspodsol* oder, wie man hier sagen könnte, *Torfpodsol* eine sehr grosse Rolle. Torf podsol ist ein Boden, wo die Humusdecke, der A-Horizont, als eine dünnere oder dickere Torfdecke ausgebildet ist, und wo Anreicherung von braunschwarzen Humusverbindungen die B-Schicht dunkel gefärbt hat. Der Torfpodsol ist fast immer mit einem hohen Grundwasserstand verknüpft. Es gibt auch grosse Flächen, wo das Grundwasser hoch steht. Hier finden sich auch sehr oft ausgeprägte Gley-Horizonte. Oft liegen Torfpodsol-Böden auf Abhängen, wo das

[1] Nur längs dem Bottnischen Meerbasen ist die Grenze etwas nördlicher als der Nordgrenze der Eiche gezeichnet.

Grundwasser nahe der Bodenoberfläche strömt, was mit dem undurchlässigen Gebirgsgrund und der verhältnismässig geringen Mächligkeit der Bodenarten zusammenhängt. Diese feuchten Böden auf geneigten Terrains sind oft forstlich sehr produktiv und können durch schwache Drainage noch verbessert werden. Dagegen sind die Torfpodsole auf ebenem Grund meistens unproduktiv, können aber zuweilen durch Drainage produktiv gemacht werden, forstlich oder landwirtschaftlich. Fleckenweise, ist die Bodenart unter dem Torfe gar nicht podsoliert. Man hat in diesem Falle so genannte echte Grundwasserböden (Frosterus 1914). Moore mit mächtigen Torf sind überall häufig.

In Abhängen, wo die Bodenarten besonders durchlässig für Wasser sind (Sand und Kies), kommt es vor, dass starke Grundwasserströme in den oberen Schichten der Böden sickern. In diesem Fall ist die Humusdecke ein lockerer "Mor", und das Bodenprofil ist dem braunen Waldboden ziemlich ähnlich. Es ist jedoch ganz durch das Grundwasser bedingt; eine Grube füllt sich schnell mit Grundwasser. Diese Böden sind die produktivsten Waldböden im nördlichen Schweden (Fichtenböden). Wo die Bodenart Material aus Kalkstein enthält, wirkt das Grundwasser noch stärker auf die Bodenbildung ein. Es entsteht in diesem Fall ein dicker Mull und ein brauner Bodentypus, auch bei weniger durchlässigen Bodenarten. Auf solchen Böden findet man sogar nahe der Grenze der Hochgebirgsregion eine sehr üppige Vegetation von Kräutern. Wo es nicht das Klima verhindert, finden sich auf den erwähnten Böden sehr gutwüchsige Fichtenwälder.

b. *Das südwestliche Gebiet. Temperiertes Klima mit reichlichen Niederschlägen.*—In Westschweden an der Grenze gegen Norwegen geht das nordschwedische Gebiet des Rohhumuspodsols unscharf in das etwas verschiedene südwestschwedische Gebiet, wo auch typische Braunerde vorkommt, über. Der Rohhumuspodsol überwiegt zwar in dieser Region, und die Tendenz zur Rohhumusbildung ist sehr ausgeprägt. Jedoch kommen auch grosse Areale von Braunerden vor, in Laubwäldern entstanden, auf ebenem Boden ohne irgend einen Einfluss von Kalk oder Grundwasser. Die Rohhumuspodsole sind in Nadelwäldern, Callunaheiden, Buchenwäldern, ja auch in Eichenwäldern (besonders *Quercus sessiliflora*) entwickelt. Die Rohhumusbildung kann zuweilen beträchtliche Mächtigkeit erreichen; 20–30 cm. in Nordabhängen sind gar nicht selten. Ortstein kommt vor, ist aber selten. Torfpodsole kommen teils als Saum rings um Moore vor, teils selbständig wie in Nordschweden, aber nicht so häufig wie dort. Die Rohhumusbildung ist offenbar durch den reichlichen Niederschlag bedingt, nicht wie in Nordschweden durch die niedrige mittlere Temperatur. Das Gebiet entspricht also in gewisser Hinsicht den Heidegegenden von Dänemark und Nordwest-Deutschland. Die meisten der schwedischen Callunaheiden gehören dieser Region an. Sehr grosse Hochmoore sind häufig.

Wo Tone und Lehme vorkommen, sind die Böden allgemein beackert; auch Moränen und fluvioglaziale Kies- und Sandablagerungen sind ziemlich häufig in Ackerböden umgewandelt. Wegen der reichlichen Niederschläge werden Ackerböden auf sehr durchlässigem Grunde in diesem Gebiet nicht zu trocken.

Das Gebiet fällt im grossen und ganzen mit der Verbreitung gewisser atlantischen Pflanzen zusammen. Als Ostgrenze habe ich darum eine etwas schematisierte pflanzengeographische Linie gewählt. Die Pflanzengeographen hatten schon lange die grossen Unterschiede zwischen der südwestschwedischen und der südostschwedischen Flora beobachtet. Durch die grosse Untersuchung der Torfvorräte Südschwedens seitens der Geologischen Landesanstalt Schwedens (v. Post 1926) wurde die Kenntnis der regionalen Verteilung verschiedener Moortypen und ihrer Floren sehr vertieft. Dabei stellte sich heraus, dass die Ostgrenze atlantischer Florenelemente, besonders *Erica tetralix*, ziemlich genau mit der Westgrenze gewisser kontinentaler Pflanzen, besonders *Ledum palustre*, zusammenfällt (Granlund 1925). Die *Erica-Ledumgrenze* dürfte die beste Grenzlinie zwischen dem Gebiet mehr atlantischen und dem Gebiet mehr kontinentalen Klimas darstellen. Sie stimmt auch sehr gut mit der Grenze des Gebiets grösserer Niederschläge überein (Abbildung 5).

3. *Die Region der schwach podsolierten Boden, meistens ohne Rohhumus. Temperiertes Klima mit wenig Niederschlägen*

Im östlichen Teil von Mittelschweden und Südschweden bis zu Südsmåland kommen ausgeprägte Rohhumuspodsole spärlich vor. Sie finden sich meistens nur auf Kies Sand und durch Meereswellen gespülten Moränen, also an sehr durchlässigem Grund. Der charakterisierende Bodentypus ist ein ziemlich schwach podsolierter Boden mit einem lockeren "Mor" oder Mull. Die Mullböden sind oft in alten Laubwäldern oder sogenannten Laubwiesen (mit *Quercus pedunculata*) entstanden. Neben diesen Podsolen kommen auch Braunerden vor. Wo die Bodenarten Material aus Kalkstein enthalten, sind die Böden besonders durch Mull gekennzeichnet; die Bodenvegetation besteht aus Kräutern und Gräsern, auch wenn der Wald aus Nadelbäumen besteht. Die Tonböden sind in grösstem Massstabe in Ackerböden umgewandelt. Die grossen Ackerbaudistrikte von Mittelschweden finden sich in dieser Region. Humuspodsol (Torfpodsol) ist selten. Er kommt eigentlich nur als Saum rings um Moore vor.

4. *Die Region des braunen Waldbodens. Verhaltnismässig warmes Klima, mässige oder geringe Niederschläge*

Im südlichsten Schweden ist sicher der braune Laubwaldboden mit ausgeprägtem Mull der klimatische Bodentypus, was schon Ramann auf seiner Karte (1911) erkannt hat. Wo die Nordgrenze dieser Region

gezogen werden soll, ist indessen nicht ganz sicher. Die Grenze auf der Karte ist in der Gegend der Stadt Växjö in Småland (die bemerkenswerte Ausbiegung gegen Norden) auf Grund bodenkundlicher Beobachtungen von Verf. gezogen. Westlich von hier habe ich die Grenzen der sogenannten Oligotroph-Gegend von *Hård af Segerstad* (1924) verwendet, was zur Zeit die beste Linie geben dürfte. An der Ostküste scheint die Grenze nach bodenkundlichen Felduntersuchungen etwas nördlich von Kalmar zu liegen, was jedoch ziemlich unsicher ist. Wahrscheinlich gehören die Inseln Öland und Gotland der Region an; sie sind aber leider sehr wenig bodenkundlich untersucht worden. Die Bodenarten dort sind fast überall sehr kalkreich, wodurch sie ein "südliches" Gepräge haben.

In der Region des braunen Laubwaldbodens ist dieser letztere der herrschende Bodentypus. Meistens ist er in Buchenwäldern oder anderen Laubwäldern entwickelt, die hier *nicht*, wie in der südwestlichen Küstenregion, *eine grosse Tendenz zur Rohhumusbildung haben.* Jedoch kommen auch Rohhumuspodsole hier und da auf sandigen Ablagerungen vor, besonders in dem nördlichen Teil der Region, wo kalkreiche Bodenarten fehlen (Abbildung 2). Torfpodsol (Humuspodsol) ist selten, kommt aber als Saum rings um Moore vor. Überall, wo die Bodenarten lehmig oder tonig sind (auch zuweilen in anderen Fällen), sind sie in Ackerböden umgewandelt worden. Diese zeigen vielfach eine ganz deutliche Podsolierung an, ähnlich der der deutschen und ungarischen Podsoltypen. Dies kommt auch in Gegenden vor, wo der ganz in der Nähe der podsolierten Ackerböden vorhandene Buchenwald einen typischen braunen Waldboden entwickelt hat. Die besten Ackerbaudistrikte Schwedens liegen in dieser Region, besonders im südlichen Teil Schonens, wo der Gesteinsgrund aus Kalksteinen und Schiefern besteht.

Wo die Bodenart nicht Kalksteinsmaterial enthält, findet man oft, dass der braune Waldboden allmählich in Podsol übergeht. Das trifft ein, wo man die ursprünglichen, spontanen Buchenwälder in dichte Fichtenwälder übergeführt hat. Eine Rohhumusschicht fängt dabei an, sich zu bilden, und darunter entwickelt sich bald ein dünner Bleicherdestreifen. Die Podsolierung ist hier durch den Eingriff des Menschen entstanden; der braune Waldboden ist jedoch der *natürliche* Bodentypus. Wo die Bodenart reich an Kalziumkarbonat ist, widersteht dagegen die Braunerde dem Einfluss des Nadelwaldes; dieser ist vom kräuterreichen Typus und bewirkt eine dauernde Mullbildung, was eine fortgesetzte Braunerdebildung zur Folge hat.

Schlussbemerkung über die Bodenregionen

Die klimatischen Bodenregionen Schwedens haben unzweideutig eine grosse Bedeutung für die Forstwirtschaft, für die Weidewirtschaft und für die Verbreitung der Pflanzen. In den verschiedenen Regionen spielen indessen auch die Vorkommnisse von kalkreichen und tonigen Bodenarten

eine sehr hervorragende Rolle (Siehe Abbild. 1 und 2). Jede Bodentypen-Region hat zwei "Facies": Die kalk-tonreiche und die kalk-tonarme. Der Einfluss des in den Bodenarten vorhandenen, aus dem Gesteinsgrund herrührenden Kalkes ist so gross, dass er in ökonomischer Hinsicht wichtiger und deutlicher als der des klimatischen Bodentypus ist. Neben dem Einfluss der Kalkgesteine lässt sich jedoch der des klimatischen Typus gut wahrnehmen.—Auch sonst spielen die geologischen Verhältnisse eine sehr grosse Rolle für Bodenbildung und Vegetation, da die Durchlässigkeit der Böden für Wasser und die Grundwasserverhältnisse zum grossen Teil auf den Eigenschaften *der Bodenarten* und *des Gesteinsgrunds* beruhen. Diese Umstände machen sich indessen örtlich geltend und fallen aus, wenn man die durchschnittlichen Verhältnisse grösserer Flächen, wo die geologischen Verhältnisse ziemlich ähnlich sind, berücksichtigt.

Für den Ackerbau sind die geologischen Verhältnisse viel wichtiger als die klimatischen Bodentypen, was damit zusammenhängt, dass die Bodenbildung in Schweden immer, geologisch gerechnet, sehr jung ist und darum nicht Zeit genug gehabt hat, das Substrat durchgreifend zu ändern. Der Landwirt ist auch imstande, seinen Boden durch Düngen und Bearbeiten weitgehend umzuwandeln; deswegen werden kleine Nüancen in den ursprünglichen Eigenschaften nicht wahrgenommen. Die Eigenschaften der Bodenarten dagegen, z. B. ob sie tonig, kalkig u.s.w. sind, fallen jedermann ins Auge und haben bewirkt, dass man in der Landwirtschaft vielfach die Bedeutung der klimatischen Bodentypen nicht erkannt hat. Das ist die Ursache, weshalb diese in Schweden vom landwirtschaftlichen Gesichtspunkt aus wenig erforscht sind.

Beschreibung einiger Bodenprofile

1. *Rohhumuspodsol* aus der nordschwedischen Region (Rokliden, 30 km. westlich von der Stadt Piteå entfernt, Norrbotten).

Vegetation: Fichtenwald mit Bodenvegetation von Moosen und Zwergsträuchern (*Vaccinium myrtillus* und *V. vitis idaea*).

(Analysen bei Tamm 1920, S. 246, und bei Stremme 1926, S. 117).

A_1. 10 cm. Rohhumus.

A_2. 11–12 cm. Ausgeprägte, weissgraue Bleicherde, scharf nach oben und unten begrenzt. Einzelkornstruktur.

B. 45 cm. Orterde und Ortstein. Rostrot-rostbraun gefärbt. Der Ortstein kommt fleckenweise vor, speziell wo die Mutterablagerung besonders sandig ist.

C. Graue, harte Moräne, lehmig-sandig, auch ziemlich viel Steine aus Gneis und Granit enthaltend.

2. *Rohhumuspodsol* aus der südwestlichen Region (Breared, 20 km. östlich von der Stadt Halmstad entfernt, Halland).

Vegetation: *Calluna*-Heide.

A_1. 6 cm. Ausgeprägter Rohhumus (zuweilen erreicht der Rohhumus 15–20 cm.)

A_2. 12–14 cm. Ausgeprägte Bleicherde. Oben etwas dunkel gefärbt durch kohlige Humusbestandteile, was typisch für die *Calluna*-Heiden ist. Unten grauweiss, scharf begrenzt. Einzelkornstruktur.

B. 60–80 cm. Orterde. Rostbraun gefärbt. Kein Ortstein.

C. Moräne. Lehmig-sandig, reich an Steinen aus Gneis.

3. *Podsol ohne Rohhumus* auf kalkreichem Grund, aus der östlichen, mittelschwedischen Region. (Omberg, Ostergötland).

Vegetation: Fichtenwald mit Bodenvegetation von Kräutern.

A_1. 1 cm. Waldstreu.

A_2. 40 cm. Grauer, lockerer Auslaugungshorizont, enthält Humus, dagegen nicht Kalziumkarbonat. Die Grenze gegen B ist unscharf.

B. 35 cm. Brauner Horizont mit einem Stich ins Rote. Enthält nicht Kalziumkarbonat, ist nach unten ziemlich scharf begrenzt.

C. Moräne, die kalkführend, lehmig und ziemlich arm an Steinen ist. 10–50 cm. von dem B-Horizont kommt pulverförmiges, ausgefälltes, weisses Kalziumkarbonat in Spaltrissen und als Hüllen an den Steinen vor.

4. *Brauner Waldboden* aus der südlichen Region. (Hissö, Småland, nahe der Stadt Växjö).

(Analysen bei Lundblad 1924 und bei Stremme 1926, S. 122).

Vegetation: Schöner Buchenwald.

A_1. 2–3 cm. Buchenlaubdecke.

A_2. 12–15 cm. Mull. Der Mull ist eine humusreiche Erde mit Krümelstruktur. Von Regenwürmern durchwühlt, sehr locker, braunschwarz.

B. 40–50 cm. Braunerde. Die Grenze zwischen A und B ist sehr unscharf. B hat braune Farbe und oben eine deutliche Krümelstruktur. Nach unten wird die Farbe schwächer, und die Krümelstruktur geht allmählich in Einzelkornstruktur über. Die Grenze gegen C ist sehr unscharf.

C. Sandig-steinige Moräne. Material aus Graniten und ähnlichen Gesteinen (enthält *nicht* Kalkstein).

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DIE KLIMATISCHEN BODENREGIONEN IN NORWEGEN

DR. K. O. BJÖRLYKKE

In dem gegenwärtigen Stadium der Bodenuntersuchungen ist es sehr schwer eine Karte über die klimatischen Bodenregionen in Norwegen auszuarbeiten. Selbst eine kleine Skizze muss mangelhaft werden.

Die Bodenuntersuchung hat bei uns den gewöhnlichen Weg von dem Untergrund und den geologischen Bodenarten aus eingeschlagen. Im lit. 1 ist eine kurze Darstellung über die Bodenverhältnisse in Norwegen

beim Anfang des jetztigen Jahrhunderts nach unserem derzeitigen Wissen gegeben. Aber schon 1911 (2) konnten wir beweisen, dass es auch in unserem Land, welches zum grössten Teil ein humides Klima hat, Gegenden mit aridem Klima gibt und einen diesem entsprechenden charakteristischen Boden. Hiermit war der klimatische Einfluss auf die

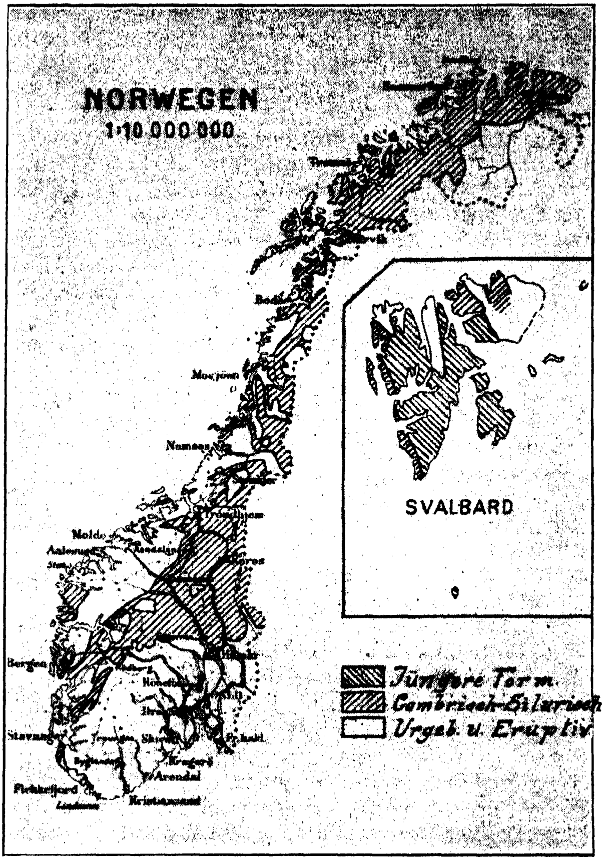

ABBILDUNG 1.—Geologische Karte von Norwegen. 1:10 Mill. Jungere Formationen (Svalbard) Gestrichelt Cambrisch-silurische Formation. Weiss: Urgebirge u. Eruptivgesteine

Bodenbildung bei uns festgestellt. Dieses ist näher in den folgenden Publikationen von 1915, 1916 und 1923 (3, 4, 5) gezeigt. Aber erst im Jahre 1924 begannen wir ein mehr systematisches Studium der Bodenprofile (8, 9). Diese Untersuchungen werden fortdauernd betrieben und sind noch nicht abgeschlossen. Mit Hülfe von Profilstudien hoffen wir, eine Übersicht über die verschiedenen Bodenprovinzen und klimatischen Bodenregionen des Landes zu bekommen.

Norwegen ist in administrativer Hinsicht in 18 Fylke eingeteilt und die Bodenuntersuchung ist auf diese Fylke verteilt. Mehrere dieser Fylke können jedoch jeweils zu Hauptgebieten zusammengefasst werden;

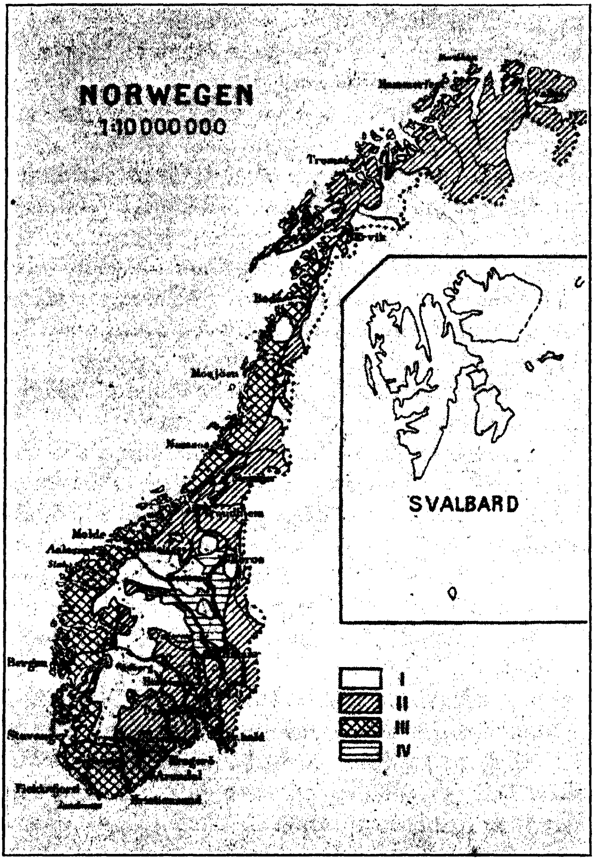

ABBILDUNG 2.—Karte der natürlichen Bodenregionen in Norwegen 1:10 Mill

I. Die Hochgebirgsregion. Arktisches Klima und mechanische Verwitterung.

II. Region mit schwachoder mässig humidem Klima. (500–1000 mm. Niederschläge). Etwas ausgelaugter Boden.

III. Region mit stark humidem Klima. (>1000 mm. Niederschläge). Stark ausgelaugter Boden.

IV. Region mit aridem Klima (<500 mm. Niederschläge). Salzreicher, nicht ausgelaugter Boden.

die wichtigsten sind das Ostland, Südland, Westland, das zentrale Norwegen, Tröndelagen und das Nordland; dazu kommen am weitesten nördlich Troms und Fumarken und Svalbard oder die Inseln Spitzbergen und die Bäreninsel im nördlichen Eismeer.

Zur Charakterisierung des Bodens in den verschiedenen Gebieten des Landes sind auch Reaktionsbestimmungen vorgenommen (10).

Aber, weder die Bodenprofilstudien noch die Reaktionsbestimmungen sind für das ganze Land fertig, und die Ausscheidung der klimatischen Bodenregionen muss deshalb z. Z. wesentlich auf die klimatischen Verhältnisse basiert werden, von denen die Niederschlagsverhältnisse die grösste Bedeutung zu haben scheinen.

Den klimatischen Verhältnissen nach kann Norwegen in 4 Regionen eingeteilt werden:

I. Die Hochgebirgsregion in Höhen über 1000 m. im Süden und etwas neidriger im Norden mit nivalem oder arktischem Klima undmechanischer Verwitterung.

II. Region mit schwach oder mässig humidem Klima. Jährliche Niederschläge zwischen 500 und 1000 mm. Mässig ausgelaugter Boden.

III. Region mit start humidem Klima. Jährliche Niederschläge mehr als 1000 mm. Stark ausgelaugter Boden.

IV. Region mit aridem Klima. Jährliche Niederschläge weniger als 500 mm. Salzreicher, nicht ausgelaugter Boden.

Der Boden in Norwegen ist nicht nur vom Klima abhängig, sondern zum grossen Teil auch von der Beschaffenheit des Felsgrundes und von den geologischen Verhältnissen. Man muss insofern bedenken, dass der Boden des Landes verhältnismässig jung ist. Es ist kaum mehr als 10,000 bis 20,000 Jahre her seit die Gletschermassen der Eiszeit wegtauten und noch kürzere Zeit seit die tiefergelegenen Gebiete sich über das Meeresniveau hoben und das Steigen des Landes aufhörte (während des Bronzealters).

Speziell ist der Kalkgehalt des Felsbodens und dessen leichte Verwitterung von besonderer Bedeutung, und die geologischen Formationen haben deshalb starken Einfulss auf die Eigenschaften des Bodens, besonders in dem Teil des Landes, welcher dauernd über dem Meeresniveau gelegen hat (das frühere supramarine Terrain), weniger in dem Teil, welcher sich in der spätund postglacialen Zeit aus dem Meere erhob (das frühere submarine Terrain), wo sich also um die marinen Ablagerungen befinden in Gestalt von Meereston und marinen Terrassen.

A. Der Untergrund der Bodenarten

Ungefähr die Hälfte des Felsgrundes von Norwegen gehört der archäischen Formation an und besteht aus Graniten, Gneisen und anderen krystallinischen schwer verwitterbaren Schiefern. An einzelnen Orten kommt krystallinischer Kalk oder Marmor vor, aber solche Vorkommen sind in dieser Formation ziemlich selten. Nahezu ein Drittel des Felsgrundes gehört zur kambrisch-silurischen Formation und diese kann wiederum in die stark metamorphe Serie im westlichen, zentralen und nördlichen Teil des Landes (längs der alten norwegischen (kaledonischen)

Gebirgskette) und die wenig metamorphe Serie im südöstlichen Norwegen (Oslogebiet) eingeteilt werden. Diese Formation ist besonders im Osten reich an Kalksteinen. Endlich gibt es hie und da noch ein geringes Vorkommen von Devon und einigen jüngeren eruptiven Gesteinsarten (Graniten, Syeniten, Porpfyren und Gabbro).

Die losen Erdschichten bestehen im höher gelegenen früheren supramarinen Terrain wesentlich aus Moräneablagerungen und etwas Kies und Sand fluvioglacialen Ursprungs. Im tiefer gelegenen, früher submarinen Terrain gibt es grössere und kleinere Flächen mit Lehmen, Tonen und Sand. Torfmoore finden sich im ganzen Lande. Ihre Ausdehnung ist auf 12,000 km.^{2} oder 3.7 % vom Areal des Landes veranschlagt. Die Hauptbodenarten Norwegens sind Moräne-, Sand-, mariner Lehm- und Torfboden, aber sie kommen meistenteils in den tiefer gelegenen Gegenden sehr zerstreut zwischen hervorragendem Felsboden (Felskuppen) und waldbedeckten Flächen (Höhenzügen) vor. In den höher gelegenen Strichen des Landes gibt es die mehr unfruchtbaren Hochgebirge.

B. Das Klima

Die Küsten Norwegens sind dem atlantischen Ozean zugekehrt und haben deshalb ein ausgeprägt ozeanisches Klima, das vom warmen Golfstrom beeinflusst ist. Die mittleren Teile des Landes haben dagegen ein mehr kontinentales Klima mit grösserer Sommerwärme und strengeren Wintern.

Das Land erstreckt sich über etwa 13 Breitengrade (57° 58′–71° 11′) und beinahe 27 Längengrade (4° 30′ – 31° 10′). Die grosse Ausdehnung besonders in Richtung Nord-Süd verursacht dass die Temperaturverhältnisse im südlichen Teil von denen des nördlichen Teiles sehr verschieden sind.

Tabelle 1 zeigt die Temperaturverhältnisse verschiedener Teile Norwegens.

Tabelle 2 gibt die mittlere Niederschlagsmenge an.

C. Die klimatischen Bodenregionen

Der klimatische Einfluss auf den muss in Erdprofilen studiert werden, diese sind jedoch etwas von den örtlichen Verhältnissen, von der Lage im Terrain, vom Niveau des Grundwassers und von der Höhe über dem Meere d.h. dem Alter des Bodens oder der Zeit, während welcher derselbe unter dem Einfluss der Atmosphärilien gestanden hat, abhängig. Obgleich die Untersuchung dieser Verhältnisse noch nicht soweit wie wünchenswert fortgeschritten ist, sind wir doch in Norwegen darüber klar, dass man mehrere klimatische Bodenregionen unterscheiden kann, wie schon eingangs erwähnt wurde. Der für die Bodenbildung wichtigste klimatische Faktor scheint der Niederschlag zu sein. Die Temperatur

hat gewiss auch einen Einfluss, vielleicht besonders auf die Art der Humusdecke, aber dies ist noch nicht genauer studiert. Auch der Einfluss der Vegetation auf das Bodenprofil ist bei uns noch keiner eingehenden Untersuchung unterworfen gewesen. Bei dem begonnenen Bodenprofilstudium haben wir uns darauf beschränkt Profile der natürlichen Bodenarten mit wilder Vegetation und Profile kultivierter Bodenarten von einander zu unterscheiden. Bei diesen beiden lässt sich der klimatische Einfluss feststellen.

Der gewöhnilche Typus ist der Auslaugungsboden, der auch als Podsolboden bezeichnet worden ist, aber der echte Podsol ist doch nur eine Varietät, welche sich nur an einigen Orten deutlichentwickeltfindet.

Unter echtem Podsol versteht man nach Glinka (die Typen der Bodenbildung, pag. 69) "einen Boden, der einen scharf undvolkommen entwickelten weisslichen Horizont A_2 besitzt." Ein solcher weisslicher Horizont A_2 ist selten an den Stellen entwickelt, wo der Niederschlag am grössten und die Auslaugung des Bodens am stärksten ist. Andrerseits ist der Boden im mittleren Norwegen nicht ausgelaugt, aber besonders reich an löslichen Salzen in der obersten Bodenschicht, ebenso wie der Boden in den ariden Landstrichen. So bekommen wir zwei Hauptregionen: Die Region mit ausgelaugter Erde und die Region mit bereicherter Erde. Aber die Auslaugungsregion kann wieder nach der Stärke der Auslaugung in eine Region mit nur mässiger Auslaugung und eine Region mit starker Auslaugung eingeteilt werden. Dazu kommt der Boden in den Hochgebirgen unter den alpinen Verhältnissen und Verwitterungsbodenarten des Felsobdens, wo die Verwitterung einen wirklichen Bodentypus noch nicht hat hervorbringen können.

1. *Die Region der mechanischen Verwitterung oder die Hochgebirgsregion*

Diese Region, deren grösster Teil im Süden höher als 1000 m. und somit über der Baumgrenze liegt, hat wenig ökonomische Bedeutung und ist bisher auch nicht genauer studiert. Das arktische oder nivale Klima mit zum Teil reichlichem oder variierendem Niederschlag bewirkt durch Frost eine mechanische Verwitterung und der Boden wird danach den Charakter der Bergart des unterliegenden Fels grundes annehmen.

Man bekommt in diesem Strich unseres Landes ausser Moräneboden und glaciofluvialen Bildungen wesentliche Phyllitboden, Gabbroboden, Granitboden und nackte Felsen, z. T. auch Schnee und Eis und grössere oder kleinere Gebirgsseen. Hier ist die Heimat der Renntiere und der Schneehühner und stellenweise auch Weide für Kühe und Schafe zur Sommerzeit. An einigen Stellen, wo die Vegetation eine geschlossene Decke bildet kann man typische Podsolprofile treffen. Aber weder die Profile noch der Humus sind in diesen Gegenden bei uns genauer studiert.

2. *Region mit schwach oder mässig humidem Klima*

Diese Region umfasst die Gegenden—besonders im Ostlande—wo die Niederschlagsmenge zwischen 5 und 600 mm. bis etwa 1000 mm. variiert. Im Norden und Süden dürfte vielleicht ein Unterschied sein, dieses ist jedoch noch nicht näher untersucht. Im Süden (im Ostlande) kommen in den tiefer gelegenen Strichen am meisten Tone und Lehme, im Norden und in höher gelegenen Strichen meist Moräne, fluviale und fluvioglaciale Kies- und Sandablagerungen vor. Im südlichen Gebeit gibt es auch den meisten Ackerboden. Die marinen Lehmbodenarten können dem Verwitterungsgrade nach in Blau-, Grau- und Weisslehm eingeteilt werden.

Den *Blaulehm* gibt es in Niederungen und in geringer Höhe über dem Meer. Er ist wenig verwittert und seine Farbe blau wie die ursprüngliche Bodenart.

Beispiel 1. Blaulehmprofil N W Frydenhaug, Aas. Gesenkte Lage, etwa 95 m. ü. M. Ackerboden. Mittlere Niederschlagsmenge 759 mm.

Chemische Analyse (10 % Salzsäureextrakt):

	A (0–20 cm.)	B (20–30 cm.)	C (40–50 cm.)
	%	%	%
N	0.30	0.09	0.04
P_2O_5	0.14	0.16	0.16
K_2O	0.11	0.16	0.17
CaO	0.57	0.49	0.41
Fe_2O_3	3.39	4.19	3.80
Glühverlust	8.78	3.71	1.80

Der Boden ist kalkreich und die Kalkmenge nimmt nach der Tiefe zu eine Kleinigkeit ab; Kali und Phosphorsäure nehmen dagegen zu. Die Eisenverbindungen sind in der Pflugsohlenschicht (B) ein wenig angereichert. Der Boden is wenig ausgelaugt.

Die Reaktion: A, pH = 4.79; B, pH = 5.40; C, pH = 5.30.

Beispiel 2. Graulehmprofil, im Park, Aas. Ebene tiefe Lage, ca. 70 m. ü. M. Wiese. Untergrundserde grau- und braungefleckt.

Chemische Analyse:

	A (0–20 cm.)	B (25–30 cm.)	C (ca. 50 cm.)
	%	%	%
P_2O_5	0.13	0.06	0.13
K_2O	0.03	0.03	0.02
CaO	0.24	0.20	0.25
Fe_2O_3	8.10	8.10	10.35
Glühverlust	10.80	4.52	4.73

Der Boden is ärmer an Pflanzennährstoffen, besonders die Pflugsohlenschicht (B). Keine deutliche Anreicherungsschicht.

Die Reaktion: A, pH = 6.0; B, pH = 6.1.

Beispiel 3. Weisslehmprofil. Im Wald östlich vom Versuchsfeld für Gemüse, Aas. Flache, hohe, etwas sumpfige Lage. Fichtenwald mit

Kräutern, ca. 100 m. ü. M. Die Untergrundserde weiss bis bleichgrau mit einzelnen braunen Punkten.

Chemische Analyse:

	A (0–10 cm.) %	B (10–20 cm.) %	C (40–50 cm.) %
N	1.57	0.40	0.04
P_2O_5	0.34	0.05	0.08
K_2O	0.10	0.05	0.11
CaO	0.41	0.07	0.11
Fe_2O_3	1.19	2.56	4.54
Glühverlust	32.04 (Asche)	14.50	3.05

Die B-schicht am stärksten ausgelaugt, keine deutliche Anreicherungsschicht.

Die Reaktion: A, pH = 4.2; B, pH = 4.9; C, pH = 5.6. Die Reaktionszahlen deuten auch auf eine Auslaugung in den oberen Erdschichten hin, besonders in der B-schicht, welche hier A_2 entspricht.

Beispiel 4. Profil in bebautem sandreichem Moränekies. Topfversuchshaus Vollebäk, Aas. Hohe Lage, ca. 100 m. ü. M. Ackerboden. Das Profil zeigte zu oberst dunkelgraue Muttererde (A) 20 cm., darunter bräunlichen Moränekies (B), der nach der Tiefe zu bleicher und mehr grau wurde (C).

Chemische Analyse:

	A (0–20 cm.) %	B (20–30 cm.) %	C (50–60 cm.) %
N	0.25	0.10	0.04
P_2O_5	0.19	0.15	0.21
K_2O	0.06	0.04	0.03
CaO	0.24	0.16	0.15
Fe_2O_3	2.74	2.59	2.46
Glühverlust	6.50	2.98	1.48

Die mineralischen Pflanzennährstoffe (ausgenommen Phosphorsäure) nehmen nach der Tiefe zu etwas ab. Dieses deutet auf geringe Auslaugung.

Die Reaktion: A, pH = 4.72; B, pH = 5.22; C, pH = 5.15.

Beispiel 5. Podsolprofil in natürlichem Fichtenwald östlich von Mysen, Ostfold. Ca. 150 m. ü. M. Hohe Lage. Mittlere Niederschlagsmenge 668 mm. (Örje). Der Boden feiner Sandboden in einer Tiefe von 47 cm. auf Lehm ruhend. Das Profil zeigte zu oberst eine Humusschicht (A_1) 5 cm., Bleicherde (A_2) 12 cm., rotbraune Rosterde (B) 17 cm.; darunter eine bleichere gelbbraune Schicht (C) 13 cm., welche auf grauem Lehm (D) ruht.

Chemische Analyse:

	A (0 – 17 cm.) %	B (17 – 34 cm.) %	C (34 – 47 cm.) %	D (47 – 55 cm.) %
N	0.08	0.07	0.03	0.05
P_2O_5	0.01	0.05	0.09	0.08
K_2O	0.01	0.02	0.05	0.06
CaO	0.03	0.08	0.14	0.12
Fe_2O_3	0.46	1.81	1.86	4.30
Glühverlust	3.62	3.36	1.88	2.97

Das Profil zeigt Auslaugung, aber keine deutliche Bereicherungsschicht. Die löslichen Mineralstoffe scheinen nach der Tiefe zu zuzunehmen.

Die Reaktion: A, pH = 5.20; B, pH = 5.20; C, pH = 5.32; D, pH = 5.25.

Die fünf obenstehenden Beispiele von Profilen geben einen Begriff von den Böden der schwach humiden Region. Sie zeichnet sich durch geringe Auslaugung der oberen Schichten aus, hat aber keine deutliche Anreicherungsschicht ausgenommen in der Farbe beim Podsolprofil.

In dieser Region kommen auch Profile vor, die einem Braunerdeprofil ähnlich sind.

Beispiel 6. Profil in humusreichem Sandboden bei Fredriksvern (Larvik), etwa 30 m. ü. M., bebauter Boden. Das Profil zeigte zu oberst humusreiche Muttererde (A), 20 cm., eine dunkelbraune Pflugsohlenschicht (B) 15 cm. und einen hell bräunlichen Untergrund (C).

Chemische Analyse:

	A (0 – 20 cm.) %	B (20 – 35 cm.) %	C (35 – 50 cm.) %
N	0.27	0.14	0.04
P_2O_5	0.07	0.05	0.07
K_2O	0.01	0.01	0.02
CaO	0.29	0.20	0.14
Fe_2O_3	1.37	2.13	1.84
Glühverlust	7.36	7.82	1.82

Hier nimmt der Kalkgehalt nach der Tiefe zu ab und der Eisengehalt ist in der Pflugsohlenschicht eine Kleinigkeit angereichert. Die Auslaugung scheint nicht bedeutend zu sein.

Die Reaktion: A, pH = 5.9; B, pH = 5.8; C, pH = 5.9.

3. *Die Region mit stark humidem Klima*

Diese Region umfasst Gebiete mit grossen Niederschlägen, jährliche Niederschlagsmengen zwischen 1000 und 2000 mm., zuweilen noch mehr. Sie streckt sich über das Südland und die Westküste. Der Boden ist hier mehr ausgelaugt mit stark saurer Reaktion.

Beispiel 7. Profil in Moränekies mit Heide bewachsen bei Bryne, Jaren, südlich von Stavanger. Hohe Lage, etwa 30 m. ü. M. Das

Profil zeigte oberst Calluna-humus, (A) 10 cm., darunter bräunlichen Kies (B), 30 cm., welcher nach unten hin heller und grau wurde (C). Der Farbe nach könnte es als ein Braunerdeprofil bezeichnet werden.

Chemische Analyse:

	A (0–10 cm.)	B (10–40 cm.)	C (40–50 cm.)
	%	%	%
P_2O_5	0.03	0.05	0.09
K_2O	0.001	0.01	0.04
CaO	0.10	0.08	0.13
Fe_2O_3	3.15	3.13	2.36
Glühverlust	10.78	4.98	1.25

Die Mineralstoffe ausgenommen die Eisenverbindungen sind stark ausgelaugt.

Reaktion: A, pH = 3.64; B, pH = 4.83; C, pH = 5.53. Auch die Reaktion deutet darauf hin, dass der Boden stark verwittert ist.

Beispiel 8. Profil im mit Heide und Gras bewachsenen Moränelehm bei Björheim, Jären. Abschüssige Lage, ca. 130 m. ü. M. Das Profil zeigte zu oberst eine schwarzbraune Torferde (A), 25 cm., brauner humushaltiger Moränelehm (B) 15 cm., gelber Moränelehm (C) 10 cm., grauer Moränelehm (D) in Tiefe von einem Meter.

Chemische Analyse:

	A (0–25 cm.)	B (25–40 cm.)	C (40–50 cm.)	D (50–100 cm.)
	%	%	%	%
N	1.58	0.44	0.06	0.05
P_2O_5	0.18	0.02	0.08	0.09
K_2O	0.10	0.03	0.04	0.07
CaO	0.16	0.07	0.11	0.20
Fe_2O_3	1.43	0.74	3.41	2.51
Glühverlust	14.10	22.3	3.69	2.11

Die B-schicht zeigt starke Auslaugung, die C-schicht ist an Eisenverbindungen etwas bereichert.

Reaktion: A, pH = 4.15; B, pH = 5.13; C, pH = 5.07; D, pH = 5.23.

Beispiel 9. Profil im unbebauten sandreichen Moränekies mit Heide bewachsen. Koppernesstranden, Syvde bei Aalesund. Schwach abschüssige Lage, etwa 25 m. ü. M. Das Profil zeigte zu oberst einen schwarzen Heide- und Grashumus (A) 16 cm.; brauner Moränekies (B) 20 cm.; grauer Moränekies (C) 14 cm.

Chemische Analyse:

	A (0–16 cm.)	B (16–36 cm.)	C (36–50 cm.)
	%	%	%
N	0.56	0.12	0.03
P_2O_5	0.03	0.13	0.24
K_2O	0.05	0.14	0.18
CaO	0.10	0.27	0.46
Fe_2O_3	1.44	2.90	2.57
Glühverlust	18.87	5.51	1.65

Die mineralischen Pflanzennährstoffe zeigten in den beiden oberen Erdschichten starke Auslaugung. Die Eisenberbindungen sind in der B-schicht eine Kleinigkeit bereichert, dieses ist jedoch in anderen Profilen von Möre nicht immer der Fall.

Reaktion: A, pH = 4.59; C, pH = 5.25.

Beispiel 10. Profil in unbebautem Torfboden, Tjörtoft, Möre. Ebene Lage, etwa 20 m. ü. M. Das Profil zeigte zu oberst bräunliche bis schwarze, weniger in Humus verwandelte Torferde (A) 20 cm., darunter schwarze stark in Humus verwandelte Torferde (B) 20 cm., stark sandgemischten Schlamm (Gytje) von hellbrauner Farbe (C), den Grund des Moores.

Chemische Analyse:

	A (0–20 cm.) %	B (20–40 cm.) %	C (40–60 cm.) %
N	1.61	2.28	0.31
P_2O_5	0.16	0.24	0.68
K_2O	0.08	0.05	0.08
CaO	0.25	0.19	0.35
Fe_2O_3	0.98	1.86	0.87
Asche	21.70	12.17	79.05
Hyger. Wasser	12.16	22.21	6.73
Litergewicht	538 g.	640 g.	920 g.

Die am stärksten humifizierte Schicht war am reichsten an Stickstoff und Eisenverbindungen, am ärmsten an Kali und Kalk, die Phosphorsäuremenge nimmt zu, je tiefer man kommt.

Die Torfbildung scheint zur Zeit aufgehört zu haben.

Reaktion: A, pH = 4.82; B, pH = 4.16; C, pH = 4.79.

Das charakteristische für den Boden in der stark humiden Region ist, dass die oberen Erdschichten starke Auslaugung aufweisen, und dass die löslichen Salze zunehmen, je tiefer man kommt. In den Profilen findet man selten Bleicherde, und ein deutlicher Bereicherungshorizont fehlt. Zuweilen zeigen die Eisenverbindungen eine geringe Bereicherung in der B- oder C-Schicht, aber nicht immer. Im äusseren ähneln die Profile meist einem Braunerdeprofil, indem unter der Humusschicht oft direkt eine bräunliche Schicht (Rosterde) folgt, welche in den tieferen Schichten, die von grauer Farbe sind, bleicher wird.

4. *Region mit aridem Klima*

Im zentralen Norwegen—von den mittleren Teilen der Binnenseen Mjösen und Randsfjorden nach Norden, also in Österdalen, Gudbrandsdalen und Valdres—ist der Niederschlag verhältnismässig klein; er variiert meist zwischen 500 und 300 mm., indem jedoch beide Grenzen etwas uberschritten werden konnen. Hier kommen an einzelnen Stellen "Hardpan"—bildungen vor, Konkretionen von kohlensaurem Kalk, die sogenannte "Hakkemette," welche eine Krystallisation von schwefel-

sauren Kalk und Aluminum an Schieferwänden, und eine Andeutung von Salzböden, die sogenannte "Salzbittererde" ist. Letztgenannte zeigt an der Oberfläche fleckenweise Krystallisation von Salzen, die wesentlich aus schwefelsaurem Kalk (Gibs) und schwefelsaurem Magnesia (Bittersalz) und z. T. Chloriden bestehen.

Der Boden ist in dieser Region nicht ausgelaugt. Die obersten Erdschichten sind reicher an löslichen Salzen als die tieferen Schichten. Echte Podsolböden können doch in grösseren Höhen über dem Meer vorkommen.

Beispiel 11. Profil in bebautem Silurmoräneboden in Jönsberg, südlich von Hamar. Flache Lage etwa 200 m. ü. M. Das Profil zeigte zu oberst schwarze Muttererde (A) 25 cm., darunter dunkelgraue Pflugsohlenschicht mit einzelnen Rostflecken (B) 25 cm., dunkelgraue Untergrundserde meistens aus Alaunschiefermaterial (C) (Norweg. Schwarzerde) entstanden.

Chemische Analyse:

	A (0–25 cm.) %	B (25–50 cm.) %	C (50–70 cm.) %
P_2O_5	0.10	0.10	0.10
K_2O	0.10	0.03	0.14
CaO	0.36	0.30	0.31
Fe_2O_3	2.76	2.98	2.83
Glühverlust	10.26	6.44	5.83

Die Erde ist verhältnismässig reich an Pflanzennährstoffen. Reaktion: A, pH = 5.5; B, pH = 5.8; C, pH = 5.8.

Beispiel 12. Profil in bebautem, kalkhaltigen Moräneboden (Lehmreicher Moränekies) in Fjeldstad, Ringsaker nördlich von Hamar. Schwach abschüssige Lage etwa 200 m. ü. M. Das Profil grau, gleichartig, ohne verschiedene Schichten. Der Felsgrund besteht aus Sparagmit und Birikalk.

Chemische Analyse:

	A (0–20 cm.) %	B (20–40 cm.) %	C (40–55 cm.) %	D (2 m. Tiefe) %
N	0.27	0.16	0.14	0.05
P_2O_5	0.23	0.22	0.23	0.17
K_2O	0.04	0.03	0.02	0.04
CaO	0.65	0.58	0.54	0.35
Fe_2O_3	3.22	3.10	3.24	3.57
Glühverlust	7.16	5.15	2.73	2.05

Die Pflanzennährstoffe sind am reichsten in der obersten Schicht vorhanden und nehmen nach der Tiefe zu ab.

Reaktion: A, pH = 6.89; B, pH = 6.83; C, pH = 6.91; D, ph = 6.15.

Beispiel 13. Profil in bebautem Silurmoräneboden bei Gran, Hadeland, süd-westlich von Hamar. Abschüssige Lage, etwa 250 m. ü. M. Das Profil hatte eine ziemlich gleichmässige graue Farbe.

Chemische Analyse:

	A (0–20 cm.) %	B (20–30 cm.) %	C (50–60 cm.) %
N	0.25	0.09	0.06
P_2O_5	0.18	0.19	0.19
K_2O	0.08	0.05	0.03
CaO	1.08	0.56	0.53
Fe_2O_3	4.90	4.03	5.20
Glühverlust	6.76	3.00	2.48

Reaktion: A, pH = 8.50; B, pH = 7.12; C, pH = 7.30.

Beispiel 14. Profil in bebautem sandreichen Moränekies bei Evang pr Lena, Toten, südwestlich von Hamar. Hohe Lage, etwa 250 m. ü. M. Das Profil zeigte eine dunkelgraue Muttererde (A), 20 cm. und ein rostfleckige Untergrundserde (B) 30 cm. 60–70 % der Erdbestandteilee bestanden aus grobem Sand und Kies.

Chemische Analyse:

	A (0–20 cm.) %	B (20–40 cm.) %	C (50–60 cm.) %
N	0.20	0.02	0.02
P_2O_5	0.22	0.23	0.19
K_2O	0.03	0.03	0.03
CaO	0.41	0.32	0.27
Fe_2O_3	2.74	2.65	2.60
Glühverlust	5.15	1.24	1.35

Reaktion: A, pH = 5.9; 5, pH = 5.8; C, pH = 5.9.

Beispiel 15. Profil in bebautem Sandboden bei Kirkestuen, Doore, südlich von Domaas. Flache Lage, etwa 450 m. ü. M. Das Profil zeigte zu oberst dunkelgraue Muttererde (A) 20 cm., darunter einen schwach bräunlichen kieshaltigen Sand (B) 20 cm., und am tiefsten einen grauen feinen Sand (C).

Chemische Analyse:

	A (0–20 cm.) %	B (20–40 cm.) %	C (40–50 cm.) %
P_2O_5	0.22	0.12	0.11
K_2O	0.14	0.13	0.03
CaO	0.95	0.38	0.43
Fe_2O_3	2.96	3.90	3.90
Glühverlust	13.59	4.39	4.17

Reaktion: A, pH = 7.61; B, pH = 7.60; C, pH = 8.10.

Beispiel 16. Profil in bebautem feinem Sandboden in Ramstad, Skjaak, südwestlich von Domaas. (Salzbittererde). Das Profil bestand zu oberst aus einer dunkelgrauen humusreichen Muttererde (A) 24 cm., darunter eine hellgraue bis schwach grünliche Untergrundserde (B) 16 cm. und eine änhliche (C) 10 cm.

Chemische Analyse:

	A (0–24 cm.)	B (25–40 cm.)	C (40–50 cm.)
	%	%	%
P_2O_5	0.27	0.19	0.18
K_2O	0.43	0.40	0.50
CaO	0.82	0.87	0.51
Fe_2O_3	1.20	1.03	1.54
Glühverlust	7.26	1.75	0.91

Reaktion: A, pH = 8.69; B, pH = 8.81; C, pH = 8.47.

Beispiel 17. Profil in bebautem grobem Sandboden Aanstad, Skjaak (Salzbittererde). Das Profil bestand zu oberst aus grauer Muttererde (A) 20 cm., darunter aus braunem Sand (B) 20 cm., und zu unterst aus einem grauen, kieshaltigen Sand (C) 10 cm.

Chemische Analyse:

	A (0–20 cm.)	B (20–40 cm.)	C (40–50 cm.)
	%	%	%
P_2O_5	0.20	0.20	0.19
K_2O	0.20	0.22	0.16
CaO	0.77	0.28	0.37
Fe_2O_3	1.08	0.98	1.04
Glühverlust	4.14	1.38	1.49

Reaktion: A, pH = 8.68; B, pH = 8.79; C, pH = 8.55.

Die hier mitgeteilten Profile geben genügende Auskunft über das charakteristische für den Boden in dieser Region mit aridem Klima sowohl dadurch dass die obersten Erdschichten am reichsten an löslichen Salzen sind als auch durch die alkalische Reaktion, welche besonders den Boden in den Gegenden auszeichnet, die den geringsten Niederschlag haben (Doore und Skjaak, die beide im obersten Teil des Gudbrandstales liegen).

Svalbard oder die Inseln im Eismeer mit Spitzbergen und der Bäreninsel wurden dem internationalen Pariser Traktat vom 9. Februar 1920 zufolge Norwegen übergeben und macht nun einen Teil des norwegischen Königreiches aus.

Über die Bodenarten auf Spitzbergen und der Bäreninsel liegt, soweit bekannt, nur ein Beitrag von Professor E. Blanck (12) und ein Aufsatz von mir über Bodenprofile aus Svalbard (11) vor, woraus hervorgeht, dass man auf Spitzbergen eigentlich nicht von irgend welchen echten Bodenbildungen sprechen kann. Die Bodenarten bestehen im wesentlichen nur aus zerkleinerten Gesteinsarten, durch physikalische Verwitterung hervorgerufen.

Beispiel 18. Profil von der Terrasse bei Ny-Aalesund an der Kings Bay. Die Bodenart besteht aus Terrassekies mit meist scharfkantigen Bruchstücken von einer quarzitischen oder flintähnlichen Gesteinsart. Das Profil zeigte eine einförmige bräunliche Farbe, nur die alleroberste 3 cm. dicke Schicht war mit Moosen bedeckt und enthielt einige dünne Wurzelfasern.

Chemische Analyse:

	A (0–25 cm.) %	C (40–50 cm.) %
N	0.09	0.03
P_2O_5	0.04	0.06
K_2O	0.05	0.06
CaO	0.15	0.14
Fe_2O_3	2.36	2.19
Glühverlust	2.86	1.70

Der untere und der obere Teil des Profiles sind in bezug auf die Menge von löslichen Salzen nicht sehr verschieden.

Reaktion: A, pH = 5.53; B, pH = 6.18; C, pH = 5.76.

Beispiel 19. Das Profil einer schwach humushaltigen feinen Sanderde von der niedrig gelegenen Terrasse unterhalb von Hjorthamn an der Advent Bay, nur einige Meter über dem Meer.

Das Profil hatte eine einförmig graubraune Farbe ohne deutlichen Unterschied zwischen Ober- und Untergrund. Der Humusgehalt scheint aus feinen Wurzelfasern zu bestehen, die man durch das ganze Profil hindurch bemerkt.

Chemische Analyse:

	A (0–25 cm.) %	C (40–50 cm.) %
N	0.12	0.16
P_2O_5	0.14	0.14
K_2O	0.04	0.04
CaO	0.53	0.56
Fe_2O_3	5.98	6.61
Glühverlust	6.16	7.92

Reaktion: A, pH = 6.54; B, pH = 6.40; C, pH = 6.11.

Der Felsgrund auf Spitzbergen besteht oft aus Kalkstein, und infolge davon, werden auch die Bodenarten kalkhaltig und können verhältnismässig hohe Reaktionszahlen aufweisen.

Beispiel 20. Profil von der Nordküste der Bäreninsel von einer am Orte gebildeten Verwitterungserde von gelbem, kalkhaltigem Sandstein (Mittelkarbon). Die obere Erdschicht bis zu einer Tiefe von 25 cm. war von dunkelgrauer Farbe und humusreich, die untere Erdschicht war von gelbbrauner Farbe wie der darunterliegende Sandstein. Das Profil wurde ca. 31 m. ü. M. entnommen.

Chemische Analyse:

	A (0–25 cm.) %	B (25–40 cm.) %	C (40–50 cm.) %
N	0.90	0.08	0.04
P_2O_5	0.05	0.05	0.06
K_2O	0.02	0.01	0.02
CaO	0.49	2.55	3.00
Fe_2O_3	0.73	1.53	2.88
Glühverlust	25.76	3.81	4.03

In diesem Profil entdeckt man Ähnlichkeit mit dem Boden in den humiden Landstrichen, indem besonders Kalk und die Eisenverbindungen sich in der oberen Erdschicht ausgelaugt zeigen und gegen die tieferen Schichten hin zunehmen.

Reaktion: A, pH = 7.50; B, pH = 8.28; C, pH = 8.39.

Die Alkalität nimmt nach unten ebenso zu wie der Kalkgehalt; auch dies ist ubereinstimmend mit den Verhältnissen in den humiden Landstrichen.

Die Bäreninsel bildet also eine Art Übergangsglied zwischen der humiden Region im westlichen und nördlichen Norwegen und den ausgeprägt arktischen Verhältnissen auf Spitzbergen, wo die Bodenarten durch ungefähr ausschliesslich physikalische Verwitterung des darunterliegenden Felsgrundes entstanden sind.

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SCOTTISH SOILS IN RELATION TO CLIMATE AND VEGETATION

A Preliminary Study

Dr. W. G. Ogg

Introduction

The soils of Scotland have been very little studied from the climatic point of view, but a considerable amount of oecological data bearing on them has been collected by Dr. W. G. Smith in the course of his vegetation mapping. During the past few years the writer has been studying the climatic types both in the field and in the laboratory, and for several months had the benefit in the field work of the experience of Professor Veatch of Michigan Agricultural College, whose assistance and that of Dr. Smith he gratefully acknowledges. He would also thank several Continental colleagues for kindness received when visiting their countries to compare soil types.

Climatic Data

The chief factors influencing climate are latitude, distance from the sea, direction of the prevailing winds, and height above sea level.

Scotland lies on the continental shelf of northwestern Europe between latitudes 55° and 59° N., but its climate is much milder and more humid than land at corresponding latitudes on the mainland of Europe. Thus Edinburgh which is in approximately the same latitude as Moscow has a seasonal range of temperature of 19° F. (10.6° C.) compared with 49° F. (27.2° C.) at Moscow. The principal reason for the absence of extremes of temperature in Scotland is the great length of the coast line compared with the total area of the country—the humidity of the air consequent on proximity to the sea tending to modify the low temperatures of winter and the high temperatures of summer. Another reason for the absence of climatic extremes is the direction of the prevailing winds which are from the west and southwest. These winds from the Atlantic are warm and moist and have a marked influence on the climate, particularly on the climate of the west coast.

About two-thirds of the total area of Scotland lies at a height of more than 1,000 feet (305 m.) above sealevel, and approximately half the country is classed as "mountain and heath land." Except for a broad shelf along the east coast practically the whole of the northern part of the country ("the Highlands") is mountainous. Fairly extensive areas of this part of the country have an altitude of over 2,000 feet (610 m.) rising here and there to over 3,000 feet (915 m.) and the highest point, Ben Nevis, has a height of 4,406 feet (1343 m.).

Another hilly region ("the Southern Uplands") occurs in the south of Scotland and extends to the English border. The hills of this district, in contrast to the precipitous mountains of the Highlands, have flat or gently rounded summits and rarely exceed 2,000 feet (610 m.) in height.

Between these two hilly areas, lies the broad "Central Lowland Plain" which stretches across the country from the Firths of Tay and Forth in the east to the Firth of Clyde in the west.

A comparison of rainfall and orographical maps shows that in the west and south, mountainous regions correspond to regions of high rainfall but in the eastern side much of the land at high altitudes has not a high rainfall. It would appear that altitude is not as important in bringing about high rainfall as exposure to the moisture laden winds. When the prevailing winds, which are from the Atlantic, strike the mountain ranges running along the west coast, most of their moisture is precipitated. The result is that the west coast of Scotland has a much more humid climate than the east coast.

Small areas in the eastern side have an annual rainfall of less than 30 inches (762 mm.) and one or two places in East Lothian and around the Moray Firth less than 25 inches (625 mm.). About a third of Scotland has a rainfall of 30 to 40 inches (762–1016 mm.) and this consists chiefly of the broad shelf of low country on the eastern side. Great parts of the "Highlands" and "Southern Uplands" have a rainfall of 40 to 60 inches (1016–1624 mm.) and considerable areas in the "Western Highlands" 60 to 100 inches (1524–2540 mm.). There are records from several places in the west, some of them at no great altitude, of over 100 inches and a 19 years' record from the observatory on the summit of Ben Nevis has given an average of more than 150 inches (3833 mm.).

The rainfall is comparatively evenly distributed throughout the year, and the relative humidity is high. Cloud and mist are more prevalent than the rainfall figures would indicate and only small areas of Scotland have more than 1300 hours sunshine per annum.

There is also considerable difference in temperature between the east and west coasts. The mean January temperature varies from 38° F. (3.3° C.) in the east to 41° F. (5° C.) in the west, the July temperature from 58° F. (14.4° C.) in the east and south to 55° F. (12.8° C.) in the northwest and west. There are, therefore, for a small country, marked climatic differences, especially in rainfall, between the east and west coasts.

Vegetation

The humidity of the climate in Scotland is reflected botanically in the large areas of moorland and heath. According to W. G. Smith, Calluna heath and dry grassland occur on the drier humous soils and Calluna moor on the drier peats. Vegetation of this kind occupies large areas in the

eastern and northern "Highlands" rising to an altitude of 2,000 feet (610 m.) in regions where the mean annual rainfall is from 30 to 60 inches (762–1524 mm.). Above 2,000 feet Vaccinium Myrtillus is frequently dominant.

Moorland areas with deep wet peat characterized by Eriophorum, Scirpus caespitosus and Sphagnum are found extensively in central and western Scotland in districts with over 60 inches (1524 mm.) of rainfall. In these high rainfall districts there are also found stretches of wet grassland or grass moor, bearing Nardus stricta, Molinia caerulea and Juncus squarrosus.

On account of the differences in vegetation just described, the hills of the west are green and offer a marked contrast to the dark colored (Calluna) hills of other parts of Scotland.

The "Southern Uplands" are covered with grassy or heathy moorland and provide some of the best grazing in the country.

Above 2,000 feet (610 m.) a characteristic arctic-alpine vegetation begins and this extends down practically to sealevel in the west indicating that it is probably associated with high rainfall conditions. This vegetation group is characterized by an increase in the amount of Vaccinium and the occurrence of arctic-alpine plants, such as Alchemilla alpina, viviparous grasses, and arctic species or varieties of Carex, Juncus, Luzula, Draba, Cerastium, Potentilla, etc. (see W. G. Smith, "Types of British Vegetation," edited by Tansley).

Although only about 5 per cent of the total area of Scotland is now under woodland, probably the primitive forests covered most of the country to a height of 2,000 feet (610 m.) including much of what is now heath and moor. Of the native forest trees, the commonest are the Scots Pine and the Birch, and in the lower ground the Oak, but in many places Pine and Birch are also found in the lower areas. Destruction of the forest on heavy land where drainage is poor has led to the formation of bogs and deep peat, and on lighter classes of land where drainage is good, to the development of heaths and grassland.

The arable land, including permanent grassland, in Scotland amounts to only 25 per cent of the total area of the country and is confined chiefly to the "Central Lowland Plain" and the shelf along the coasts. Nearly 50 per cent of the country consists of "mountain and heathland" used for grazing and may be regarded as bearing the natural vegetation.

The crop rotations on the best land, which is found chiefly in the relatively dry belt along the east coast, consist of wheat, barley, potatoes, oats, and turnips. On the less productive soils oats, turnips, and grasses form the chief crops, and on poorer land or at high altitudes the farming is almost exclusively confined to grazing.

The limit of cultivation in most parts of Scotland is about 1,000 feet (305 m.) above sealevel and according to Smith, wheat ceases to be a

regular crop of the farm at an altitude where the mean July temperature is below 56° F. (13.3° C.) and the rainfall exceeds 32 to 34 inches (800–850 mm.) per annum.

Geology

Scotland consists largely of metamorphic, Palaeozoic and igneous rocks—materials which are predominantly siliceous. They can be conveniently arranged in three groups:

(1) Coarse crystalline metamorphics and granites (gneisses, schists, quartzites and granites). This group occupies most of the northern half of Scotland.

(2) Sedimentaries and associated volcanics (Torridon Sandstone, Old Red Sandstone, Carboniferous, andesites and basalts). Most of this group is found in the "Great Central Plain," but smaller areas occur in the northwest (Torridon Sandstone), northeast (Old Red Sandstone), and extreme south (Carboniferous and Old Red Sandstone).

(3) Fine grained metamorphics (shales, slates and greywackes). These constitute the "Southern Uplands" and are less metamorphosed than the metamorphic rocks of the "Highlands."

The whole country has been glaciated and practically all the land to an altitude of 1,000 feet (305 m.)—and in many places 2,000 feet—is covered with glacial drift. Much of this glacial drift is non-calcareous, but the writer has found considerable stretches of alkaline drift in the "Central Plain." The higher hills and steep slopes are covered with rock débris, and one or two fairly extensive alluvial deposits occur, the largest being in the valleys of the rivers Forth and Tay.

A detailed mineralogical study of the glacial drift has been carried out by Hendrick and Newlands and is at present being carried out in Edinburgh by Hart. The results so far obtained indicate that, although boulders are frequently far-travelled, the matrix of the drift—at any rate where the drift is comparatively thin—is largely derived from the underlying rock.

Description of Soil Profiles

It will be seen from the foregoing, that Scotland shows a very considerable climatic range within a small area, and since climate is now recognized as the basis of separation, at any rate in a broad grouping of soils, an examination has been made of the soil profiles of various regions showing distinct climatic differences. In studying these profiles account has also been taken of vegetation and geology.

SOILS OF THE DRIEST REGIONS

This group has been taken to include areas with an annual rainfall of less than 30 inches (762 mm.) and is limited to a narrow strip along the

east coast. The study of these areas was confined chiefly to the Lothians and Fifeshire.

Most of the land is intensively cultivated and hence the original profile and native vegetation have in most places been destroyed. Several profiles which appeared to be virgin were examined and consisted of (1) a thin surface layer (25–50 mm. thick) of leaf mould under timber or turf, and humus soil under grass, (2) a dark brown layer (75–150 mm. thick) containing a considerable amount of organic matter, (3) a yellowish-brown layer (varying in thickness up to about 300 mm.), (4) a reddish-brown or buff-brown slightly more compact layer (about 300 mm.), (5) slightly altered parent material. In the profiles examined this was frequently boulder clay over Carboniferous, or Old Red Sandstone, or their associated volcanics.

A profile on a cultivated soil near Dunbar, East Lothian, showed the following layers: (1) brown friable loam (230 mm.), (2) yellowish or reddish-brown friable loam (250–300 mm.), (3) brick red slightly compacted layer (600 mm.), (4) reddish-brown boulder clay overlying Carboniferous Limestone. The reaction was acid in the surface and alkaline in the basal layer. Differences were observed in color and in thickness of the layers on soils derived from different parent materials but thick peat, grey layer and cementation or iron pan were absent in every case. From their appearance and geographical position it is probable that these soils belong to the Brown earth group and they are probably similar to those described by Tamm in southern Sweden.

SOILS OF THE MODERATE RAINFALL REGIONS

Areas with an annual rainfall of 30 to 40 inches (762–1016 mm.) have been taken as constituting this group, which extends over about a third of the total area of Scotland and includes the bulk of the arable land. An examination of virgin profiles especially in the east and southeast parts of the country has shown that at least two classes of profiles occur.

(a) The first is practically identical with the virgin profile just described for the dry region, except that in this case there is a tendency for a grey layer to develop under the peaty surface. This tendency is seen particularly in profiles under coniferous woods which in this region are, compared with deciduous woods, much more abundant than in the drier coastal belt. The layers below the grey layer in such cases are also developed to a slightly greater extent but there is little or no evidence of cementation or iron pan formation. Profiles of this kind have been found abundantly over Carboniferous, Old Red Sandstone, and their associated volcanics in the east and southeast and also over the basic rocks of the northeast. In most cases the actual parent material was boulder clay. It was observed that the soils over the basic rocks fre-

quently had a deeper brown color and were more crumbly and friable in the surface layer than those over the non-basic materials.

At many places within this rainfall range, a modification of this type is found which appears to have developed under, or been altered by, high moisture conditions near the surface. Profiles of this kind are frequently met with where forests have been destroyed, or cut down and not replanted. A marshy condition often results during part of the year and the profile shows the "glei" horizon described by Russian writers. The following example is from East Lothian and developed from boulder clay over the Calciferous Sandstone series of the Lower Carboniferous under an annual rainfall of about 35 inches. Trees (Scots Pine) had been cut down and were replaced by heather, natural grasses, and rushes. The layers of the profile were as follows:

(1) Surface peaty mould (50–75 mm.).
(2) Friable yellow fine-sandy loam (130–175 mm.).
(3) Grey and yellow mottled heavy layer (about 100 mm.).
(4) Chocolate brown and grey plastic gritty clay (about 300 mm.).
(5) Chocolate brown and grey (more brown) with streaks of yellow material. Slightly altered boulder clay.

Adjoining cultivated land showed a greyish brown color of the surface soil.

(b) The second type of profile met with in the 30 to 40 inch (762–1016 mm.) rainfall regions shows distinct differences from those described above. The same succession of layers was found to occur, but below the peaty layer there was often a distinctly greyish layer having a thickness of ½ to 2 inches (12.5–50 mm.). Below this, there was often evidence of cementation and iron pan formation. An example of this type from a friable boulder clay over granite in Aberdeenshire showed the following layers:

(1) Litter and blackish peat (50–75 mm.). Vegetation Coniferous Wood.
(2) Greyish leached layer (50–75 mm.).
(3) Coffee-brown layer (12.5 mm.). Thin iron pan in places.
(4) Yellowish-brown non-cemented layer (200–250 mm.).
(5) Compact mottled and sometimes cemented layer.

Profiles of this kind were frequently met with on the granitic drifts of Aberdeenshire. The drift as a rule was very gravelly and pervious. Probably this and the composition of the parent rock would account for the differences in profile development compared with group (a).

The natural vegetation in the area examined was frequently pine wood, or heath which may have been formerly pine wood. Similar profiles

were found in the "Southern Uplands." It seems likely that these soils belong to the podsol group, whilst group (a) may be described as podsolic.

SOILS OF THE HIGH RAINFALL REGIONS

The high rainfall areas are confined largely to the hilly districts of the west of Scotland. The profiles are characterized by a thicker peaty covering, a better development of the bleached horizon and a thicker brown layer beneath it, than any of the varieties previously described. The brown layer is sometimes several feet in thickness and this is frequently accompanied by iron pan and cementation. Considerable differences in development of this type were observed:

A profile developed under fairly good drainage conditions from boulder clay overlying Old Red Sandstone (rainfall over 60 in. = 1525 mm.) showed the following succession of layers:

(1) Litter and peaty layer (100 mm.).
(2) Grey layer (50–75 mm.).
Iron pan.
(3) Coffee-brown layer (75 mm.).
(4) Brown layer with much grey mottling (150 mm.).
(5) Brown layer with grey mottling—more compact but still friable and containing black specks (150 mm.).
(6) Cemented layer (225 mm.).
(7) Parent material.

In places where the peat was more than about 6 to 8 inches (150–200 mm.) thick, the bleached layer was rather dark in color and mixed with streaks of blackish organic matter. A thick development of grey material, mottled with rusty brown spots and streaks, took the place of the brown layer of profiles with thin peat. An example developed from boulder clay over Old Red Sandstone in a region of well over 40 inches (1016 m.m.) rainfall showed the following layers:

(1) Surface well decomposed peat (150–300 mm.). Vegetation Nardus, Scirpus, Aira caespitosa and Juncus.
(2) Grey layer with putty-like texture—abundant black specks (150–300 mm.).
(3) Grey and yellow mottled layer rather heavier in texture (300–450 mm.). Incipient pan in places.
(4) Reddish fairly plastic boulder clay—slightly altered parent material.

This last type of profile occurs in regions of poor drainage and probably corresponds to the "humus podsols" described by Frosterus, in Finland, and Tamm, in Sweden.

MOOR SOILS

Considerable areas of these occur all over Scotland, and it seems probable from the tree remains, that in many places the moor soils were formerly podsols and that after the destruction of the original forest the podsol changed to the moor type. Like the "glei" podsols formed under poor drainage conditions they are characterized by a surface layer of peat of varying thickness, followed by grey yellow and drab-brown mottled layers, streaked and spotted by iron compounds.

SKELETAL SOILS

On the hill slopes, the formation of mature profiles has frequently been prevented by downwashing and soil creep. On such areas, even in districts of high rainfall, the peaty layer is sometimes absent, and the grey leached layer is often ill-defined or obliterated, leaving a brownish mineral layer on the surface. All stages may be seen from more or less complete profile to entire absence of profile.

ANALYTICAL DATA

Data on the mechanical analysis, ultimate chemical analysis, reaction, exchangeable calcium and "lime requirement" of the soils of the low and medium rainfall districts of the southeast of Scotland (about to be published by the writer) support the following conclusions:

(1) There is a lower percentage of the finest fractions (fine silt and clay) in the surface than in the lower horizons, but as a general rule there is not a marked accumulation in the B horizon.

(2) There is a higher percentage of SiO_2 (about 10 per cent higher in the soils examined) and a lower percentage of Fe_2O_3 (about 9 per cent lower) in the surface than in the subsurface layers, but again there is no well-marked zone of accumulation of Fe_2O_3.

(In both mechanical and chemical examination the surface peaty layer A_0 was not analysed).

(3) The pH of the majority of the cultivated soils examined is between 5 and 6.5; the "lime requirement" (by the Hutchinson and MacLennan method) 0.05 per cent to 0.25 per cent $CaCO_3$; and the exchangeable calcium content 0.1 per cent to 0.45 per cent CaO. Long unploughed soils from the same area, have a lower pH (4.5—5.5), a lower content of exchangeable calcium and a higher "lime requirement;" whilst woodland, hill and heath soils are characterized in their surface layers by an extremely low pH (below 5 as a rule), a low content of exchangeable calcium (usually less than 0.1 per cent CaO) and a high "lime requirement."

(4) Although the majority of the soils, irrespective of their stratigraphical formation are of acid reaction, a certain amount of connection has been observed between the reaction and the nature of the underlying

rock. The soils over the Carboniferous Limestone series of the Lower Carboniferous are the most basic and those over basic volcanic rocks, alluvium and old Red Sandstone conglomerate are, as a rule, less acid than the remainder. The relationship with geology might be clearer were more data available on the petrographic character of the rocks.

(5) A comparison of the surface and subsurface layers shows that in the southeast of Scotland the pH of the surface layer is usually considerably lower than the pH of the subsurface layer. The "lime requirement" is usually greater and the percentage of exchangeable calcium less in the surface than in the subsurface A study of the reaction of complete profiles shows that, in general, there is a steady decrease in acidity from the surface downwards, although in some cases the immediate subsurface is more acid than the surface.

(6) Most of the samples examined in the acidity investigation were from a region of 30 to 35 inches (762–890 mm.) rainfall, but a few areas of higher rainfall were studied and it was found that samples of cultivated soils from the districts of high rainfall have a pH ranging from 4.5 to 6 whilst those from the drier regions along the east coast have a pH ranging from 5.5 to over 7.

(7) A comparison of cultivated and adjoining uncultivated land in several places shows that great changes in the reaction have been brought about by cultivation—the profiles of the cultivated soils being much less acid than those of the uncultivated.

(8) A study of the reaction of certain heath soils in relation to vegetation shows considerable differences of reaction in the different vegetation groups—Calluna and Vaccinium areas having a pH of 3.5 to 5, Ulex good and poor grass areas 4 to 4.5, Rushy and Sedgey areas 4.5 to 6.5 (in some cases due to "flushing" with water relatively rich in bases), and good grass areas 4.5 to 6.

These results obtained for the soils of the low and medium rainfall districts of the southeast of Scotland indicate that, although there is no well-marked development of a B horizon, a considerable amount of leaching has taken place, and support the view that these soils belong to the podsolic group. Marbut has pointed out that the "Brown Soils" of southern New England have the soil colloids still rather uniformly distributed throughout the profile—in other words the profile is young—whereas in Maryland, Virginia, Pennsylvania, Ohio and Indiana the profile has attained a highly advanced stage of development. From the data available, it would appear that the Scottish "Brown Earths" and podsolic soils correspond to the former group and should be classed as young soils.

In conclusion I would express my indebtedness to my colleague, Mr. W. T. Dow, for assistance with the analytical work.

ESQUISSE PRÉALABLE DE LA DISTRIBUTION DES TYPES DE SOLS EN ESPAGNE

DR. E. DEL VILLAR, Madrid, Spain

Les fondéments de cette carte sont:

(1) Un voyage rapide de première reconnaissance fait avec le Dr. Treitz, et une peu amplié après par moi; et l'étude encore très incomplet et fragmentaire fait par moi au laboratoire d'une partie des èchantillons pris dans ce voyage. Dans celui-ci la plupart de l'ouest, y la région mésophytique du nord et nord-ouest, n'ont pas été visites.

(2) L'état de nos connaissances sur la géologie et la climatologie de l'Espagne.

(3) Ma connaissance personelle de la végétation que j'étudie depuis des années.

Il y a donc dans l'esquisse beaucoup d'hypothétique.

J' ai taché d'utiliser, en tant que possible, la classification accordée pour la carte générale de l'Europe. Pour les types de sol non compris dans cette classification, j' indique ci-dessus les rapports avec les types les plus proches.

Aire montagnarde (Gebirgszone).—Obligé de faire vite, je dessine les aires de montagnes très synthétisées et avec un criterion topographique (pour le moment). Dans ces aires il ya des étendues de veritable sol de calvero (Calveroboden); du sol a bois mésophytique; du sol-squelette; du sol podsolé; de la terre noire de prairie alpine; des sols a torbiére et tourbeux, etc.

Sols bruns forestiers (Brauner Walderde).—J' assigne à cette catègorie toute la règion pluvieuse à bois feillus mésophytiques du nord et nord-ouest, prise en ensamble, et que je n'ai pas étudiée pédologiquement. C'est un hypothèse fondée seulement dans le climat et la végétation. Comme dans le nord-ouest les terrains sont tres siliceux et il y a des turbieres, je suppose que dans le sol forestier on trouvéra aussi du podsol. Dans la partie oriental de la zone côtière du nord, dominent les roches calcaires. Comme en plus le climat est très-pluvieux et il y a des sols très-humeux, je suppose que, dans le sol brun forestier il y aura aussi de *renzina.* Je laisse, avec toute l'intention, sons rayer de renzina, un coin au fond du golfe de Biscaye, ou il ya une aire géologique différante.

Sol sub-châtaigne-brun a lignetum (Unter-kartanien-brauner Geholzboden). Cette catégorie ne se trouve pas dans les pays dejà cartographiès. J'appelle ainsi, en ensamble, le sol mûr et pas encore détruit de la región nérophytique dont la végétation originaire a été le bois nérophytique a *Querues?* (*2. iten surtout, 2. faqinea, 2. suber*) ou a *Pinus* (*P. halepeusis, P. pinea, P. pinaster, P. nigra* [1]). De ce bois il restent des residus et

[1] *P. laricio* d'autres auteurs.

des temoins; mais la plupart de l'aire est, ou bien cultivée, ou réduite a des stades subseriaux par la destruction anthropogené. J'ignore si l'etude détaillé de l'avenir deridera en faveur ou en contre de la legitimité et unité de cette catégorie de sols à fondément géobotanique et par consequent purement provisionelle. Nême dans le cas qu'il soit un type, il est bien divisible en classes. En Espagne la classe siliceuse domine dans la partie *W*, depuis Sierra Morena, ou l'airè en est très-large (partie rayeé dans la carte etc.) vers le nord-ouest ou la bande devient en Espagne tres retrécie, mais j' épanche en Portugal; la classe calcaire dans le reste (intérieur, est, et ouest). Une subdivision de la classe calcaire serait la "terra-rossa," dont le problème en détail est en Espagne à étudier. Beaucoup de terrés très rouges, v. g. au plateau Sud, sont minéralogiques, dues au grés rouge triasique. Dans l'est et dans le sud-est on trouve aussi des terres plus ou moins rouges provénantes des roches calcaires, et couvrant quelque fois j' étendues assez grandes, par exemple a Valence, mais son ubication doit ètre reservée a la cartographie detailée.

Le type provisionel de *sol sub-châtaigne-brun* se rapporte d'un coté au *sol brun forestier* (=brauner Walderde), d'un autre au *sol châtaigne* (=kartanienfarbiger Boden). C'est pourquoi, à fin d'introduir le moins possible de nouvautés, je lui donne un nom derivé de ces deux types, et je mets avant la particule *sub* (=unter) parceque le général est que la couleur soit plus claire que celle des sols châtaignes, et les caractères sont atténués par rapport aux deux types cités. *Le sol sub-chât.-br.* est aussi un sol forestier comme le *sol brun;* mais il correspond a une vegetation et a un climat nérophytique (au lieu mésophytiques): en consequence il doit y avoir une différence: le *sol sub-ch.-br.* est moins humeux, et aussi moins lavé. Le *sol châtaigne* est aussi nérophytique comme le *sol sub-chât.-br.*, mais celui ci est forestier et l'autre non; et le *sub-chât.-br.* est aussi moins riche en humus (beaucoup moins d'ordinaire) que le sol *châtaigne*.

L' etablissement de ce type (pour le moment provisionel et a confirmer par l'étude détaillé) peut resoudre, pour la carte provisionelle, le probléme des sols méditerranéens et d'autres regions nérophytique temperées ou subtropicales. L'aire que Marbut signale au nord de l' Afrique comme "chestnut-brown soil" doit être assignée à mon type de *sol sub-châtaigne-brun*. Ma dénomination est presque la même de Marbut (et c'est une raizon de plus en faveur de celle-là); mais Marbut emploi celle de *chestnut-brown-soil* comme synonyme de *Kartanienfarbiger Boden* et embassant dans l'ensemble les soils aussi nommés à graminetum nérophytique du SE. de la Russie et de l'interieur de l'Asie. Le caractère forestier originaire et le pouvrété (au lieu de richesse) en humus obligent à faire pour les sols méditerranéens et analogues un type différent.

J'ai formé mes idées sur ce point après le départ du Dr. Treiz, et j'ignore comment il aura resolu le problème.

Les sols appelés jaunes doivent aussi être compris dans cette catégorie plus générale de *sols sub-chât.-br.* Comme la denomination de *jaune* ne serait pas propre souvant, et d'autre part elle n'a pas été appliquée qu' à une partie, et encore non bien definie, des sols mediterranéens, elle ne peut pas être utilisée pour le type *sub-chatâigne-brun*, ce qui justifie la création de cette autre.

Sol de calvero (=Calveroboden).—Une grande partie des sols forestiers nérophytiques dont je viens de parler, n'on pu mûrir, à cause du terrain trop accidenté et trop pierreux, en combinaison avec le climat sec, et ça même la ou le bois nérophytique est conservé. Dans une partie plus grande encore le *sol sub-châtaigne-brun*, qui etait arrivé a mûrir, a été detruit comme consequence de la destruction de la vegetation naturelle, du paturage en farme primitive qui est venu aprés le bucheron (et meme avant), et de l'action du climat sur la terre denudée. La végétation recommence toujours sa série; mais elle ne peut arriver aux stades avancés. Le plus généralement elle ne depasse celui de *tomillar* ouvert, plus ou moins parsemé de petits abbrizzeaux. Entre les plantes ou voit la terre une, souvent dans une proportion qui depasse le 50 per cent. En Espagne, spécialement en Castille, ou comme ce paysage *calvero* (derivé de *calva* =clarière). Le sol y est donc fragmentaire, reduit à la rhizosphère de chaque pied de plante ou touffe de plantes; unistrate; et très peu profond (souvent 20 cm.). Le Dr. Treitz ayant demandé mon avis sur la dénomination de ce type de sol, je lui ai proposé, la deriver du nom local, a l'vistar de "podsol," "tchernosiom," etc. C'est pourquoi j'adopte la dénomination de *sol de calvero* (=Calverboden). Ces sols ne retrouvent aussi tout autour de la Méditerrannée au sud-ouest des Stats-Unis, en Argentina, etc.

Que dans toute l'entendue (prise d'ensemble) que ne signale dans ma carte, ce sont ces sols qui dominent, ça n'est pas aucune hypothèse; c'est un fait absolument certain.

La distribution entre *sol sub-châtaigne-brun* et *sol de calvero* tient a ce que le sol plus ou moins mûr c'est conservé surtout, dans les contrées plus plates, dans celles plus siliceuses ou argileuses et moins pierreuses (comme il est la regle dans l'aire calcaire), dans celles qui farment pied-de-mont, ce qui favorise sa teneur eu eau, et dans la bande cotiere ou le climat n'est pas excessivement sec.

Il y a á l'ouest de Salamanca un petit coin que je n'ai pas visité; ces est pourquoi j'y mets simplement une *?*, ne sachant pas si c'est le *sol sub ch.-br.* ou le *sol de calvero* qui y domine. Dans une partie de aire non calcaire du bassin de la guardiana, ou de considerables étendues de néroquercetum se conservent encore, la séparation des deux sols correspondra à la cartographie detailleé. Pour le moment je signale simplement en bandes la presémes des deux.

Terrains sabloneux a pineraie et a dunes. Je n'ai pas encore pu faire

des coupes ni etudier des échantillons de ces deux taches, l'une interieure au plateau nord, lautre cotière. Je doute part qu'il s'agisse de podsol (quoique celle ci aïe été la première impressíon du Dr. Treitz, dont j'ignore l'opinon actuelle). Le climat, surtout pour l'aire interiéure est *entrèmement sec.* C'est pourquoi je penche plutôt pour le caractère désertique, les arbrer puissant l'eau en profondeur. Comme j'ignore, je n'ai pas le droit de qualifier; c'est pourquoi je ne donne pas de nom a ces sols.

Terres noires. Je ne signale pas de *tchernosiom* parce qu'il n'a pas encore été descrit en Espagne. Des trois points ou l'on indique de terres noires, le plus meridional correspond a une enclave d'étangs (laguna de la Jande) et marécages a niveau changeant a brunés de l'année; c'est dont un type connu de terre noire autre que le *tchernosiom.* Le point au Sud de Cordoue correspond au même type de végétation que le reste de la contrée (*campiña de Córdoba*): originairement le bois nérophytique, aujourd'hui la culture. Il est à rechercher si la couleur noirâtre, très localisée, ne pourrait tenir à la préseme de schistes anthracolithiques dans la roche mère; puisque les terrains anciens de la rive droite du guadalquivir ou figurent des gissements de charbon, affleurent quelque fois dans l'aire plus moderne de la rive gauche. Le troisieme point, au plateau nord, corresponde a la Moraña, une contrée voucé de longtemps a la culture céréale, et que je n'ai pas etudiée.

Enclaves salées: Elles ne sont pas climatiques, mais géologiques, et localisées, au moins celles de l'interieur. Jusqu'a present on n'a pas encore trouve en Epagne du carbonate de sodium ou alcali noir. A la Mancha (plateau sud) ou trouve des nitrats; la meme aussi, et dans le reste, il s'agit de sulphats et de chlorures.

Alluvions fluviaux dans les vegas. Etant donnee l'enorme étendue du *sol de calvero,* il sérait difficile à comprende comment y pourrait vive la population. Tout le pays nérophytique est traversé ou passemé de *vegas* et *huertas.* Les "vegas" sont les vallées fluviales, frequemment trés emaissées. L'eau edaphique y donne lieu a une vegetation naturelle mésophytique a *Populus, Salin, Ulmus, Tamarin,* etc.

Dans la cote meridionale on appelle "*vegas*" a la partie elargie des vallées fluviales près de l'embouchure, ce sont des valleés cotierès. Ces mêmes accidents sont apeplés "*huertas*" a la côte orientale. Quelques unes sont des amiennes plaines cotières salées, améliarées et conquises a l'agriculture. C'est la surtout qu'on cultive l'oranger et la palme à dattes. Dans les *vegas* cotierès du sud on cultive la canne à sucre; dans celles de l'interieur on cultive beaucou la betterave sucrière. Le sol des "huertas" et "vegas" differè donc du sol nérophytique *sub-châtaigne-brun.* Dans les vegas de l'interieur au moins, il semble plutôt en rapport avec le *sol brun forestier.* L'étude detaillé nous dira si l'on peu les identifier. Entre-temps je me contente de signaler, *comme exemple,* dans le carte, quelque une de ci "vegas" ou "huertas" fluviales, seulement les

plus étendues et importantes; mais tout le pays en est plus ou moins croisé. Elles forment des veritables oasis dans la grande aire subdesertique à *calvero.*

Marais fluviaun et marins (Fluss-und Seemarschen). Aussi comme exemple, je signale seulement les plus étendus: au delta de l'Ebre, au delta interieur du Guadalquivir et autour de l'Albufère de Valencia. L' étendue a été enagérée pour la faire visible.

PROFILE ML—I [1]

Il correspond aux terains de l'Ecole d'Agriculture a Mardid; a l'aire géologique des sables quaternaires dans le prédemont de la Cordillerè Centrale. Il est un exemple de *sol sub-châtaigne-brun.* C'est un veritable

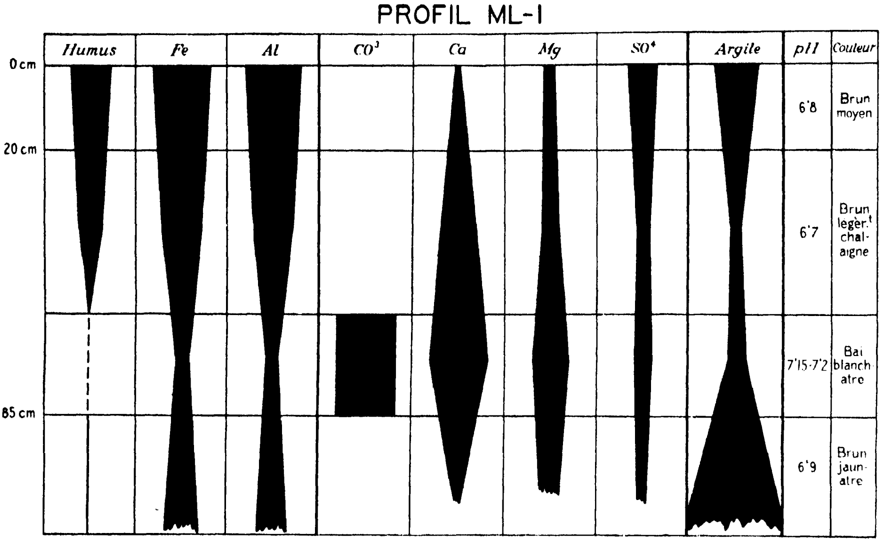

FIGURE 1.—Taches que exprime des proportions relatives d'analyse du differents horizonts

sol A. B. C. dans la nomenclature de Stremme; puis qu'il a un veritable horizont illuvial avec acumulatión de carbonats et bases terreo-alcalines. Il faut heuir campte de ce que dans la roche mère (sables provements de la detrification du quartz et du gneiss) il n'y a pas (ou presque pas) de carbonates. Une couche à carbonates plus ou moins profonde a été reconue également aux environs de Madrid dans beaucoup de points de la même aire des sables quaternaire. Mais on n'a pas le droit de generaliser d'avance les caractères de ce seul profil a toute l'aire que je nomme provisionalement de *sol sub-châtaigne-bruns.*

[1] Matieres solubles (NO_3, SO_4, Cl) dans des proportions trés petites.

La ou la roche mère est calcaire, les conditions changent. Je n'ai pas encore fait l'étude complet d'un profil analogue dans l'aire calcaire, mais j'ai fait déjà des determinations du pH et d'autres observations fragmentaires. Dans un sol calcaire a climax conservée (*pinetum halepenais* avec sourbois plus ou moins abondant) près de Segorbe (prov. de Cartellón, aire cotierè ecientale de *sol sub-chât.-br.*) j'ai trouvé, par exemple:

	Valeurs de pH
Dans la rhisosphère superficielle du sourbois	7.35
Jusqu' à 30 cm. près des pins	7.20
De 30 à 40 cm.	7.30
De 40 à 90 cm.	7.30
À 120 cm.	7.30

Ce qui fait présumer un horizont éluvial (signalé por la flèche) quoique *tres peu* lavé, et plus ou moins d'accumulation au dessous. Si l'analyse confirme la présumption, ce sera un type (dans la classe calcaire) vraiment équivalent a celui du profil Ml–I (dans la classe siliceuse).

Profil P–I [1]

Il a été pris, avec le Dr. Treitz, au "monte" (bois) del Pardo-*quercetum Silices*,—la climax la plus typique de l'aire nérophytique interieure. Mais le profil ne donne pas le type général de sol de ce *quercetum;* parce qu'il a été pris trés prés de la rivière Manzanares, et au bord d'un ruisseau. Il correspond par consequent a un sol de "vega" fluviale interieure dans l'aire siliceuse. Ce sol se montre bien plus lavé et sans accumulation de carbonates. Il se raproche bien d'un sol brun forestier mésophytique.

Le *profil Ml-I* se raprochait pas contre du type de sol châtaigne, duquel il a l'horizont d'accumulation; mais il est tres peu humeux et plus lavé.

Le dessins qui répresentent ces deux profils n'ont d'autre object que celui de donner à la description une forme visuelle. La largeur des taches exprime des proportions relatives, non des valeurs absolues d'analyse quantitative. On droit comparer les largeurs des differents horizonts dans chaque colonne; non les largeurs des differentes colonnes dans le même horizont. La différente largeur dans les differentes colonnes exprime seulement la richesse relative d'une façon aprochée (les veritables tants pour cent étant dans la plupart des cas trop petits pour êtré représentés graphiquement).

[1] Les matières sòlubles dans H_2O (NO_3, SO_4, Cl) sont en proportions minimes. Les reactions de Ca et Mg (solubles) sont imperceptibles. pH= 7.0 dans le tapiz ouvert de gramini-herbetum général; 6.4 á 6.35 dans les taches de muscinetum persemmées dans les clairières du premier.

PROFIL P-I

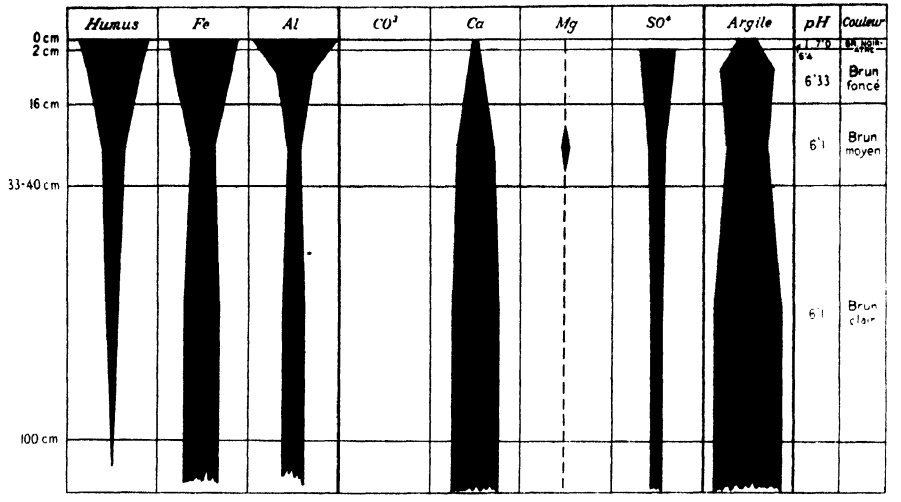

FIGURE 2.—Taches que exprime des proportions relatives d'analyse du differents horizonts

RECTIFICATION A MES NOTES SUR LES SOLS DE L'ESPAGNE

Je crois avoir dit dans ces notes que le sol *Ml-I* était un sol A. B. C. d'après la notation de Stremme, au lieu de dire de Vilensky, etc. Mes "Notes," ecrites trop à la trote à cause de la limitation du temps, ont été rédigées sous l'impression de l'extrait du travail de Vilensky (Compt. rend. Ass. Int. Sc. Sol., 1925, n. 4), qui donne le nom de *C* à l'horizont illuvial quoique l'a accumulation y soit de carbonates et de base et non de sesquioxydes, et de l'ouvrage de Shantz et Marbut sur l'Afrique, ou quand 'il s'agit d'accumulation, on se rapporte toujours à celle-ci.

Dans la notation de Stremme le symbole *B* étant exclusivement à l'horizont d'accumulation de sesquioxydes delavés d'en haut, mes sols Ml-I et P-I séraient des sols *A. C.*

Ceci laisse pourtant intactes mes notes sur le type de sol que je nomme provisionement *sub-châtaigne-brun.* En comparant mon profil Ml-I avec le tableau de Balleneger (p. 62 du livre de Stremme) et avec le tableau de Glinka (p. 85), il ressort que le type Ml-I differe du *type brun forestier* parce qu'il est moins lavé (puisqu'il y manque le véritable horizont *B* de Stremme, les sesquioxydes n'ètant pas deplacés); mais il differè aussi des *Steppenböden* num. 4, 5, 6 et 7 de la page 63, et des *Kartanine-böden* de la page 85:(1) par la manque d'une haute teneur un humus; (2) par le plus part lavage des carbonates; (3) par la manque d'une reaction alcaline (au moins dans la classe "non calcaire").

Ce qu'il reste a savoir est si réellement la coupe *Ml-I*, ou celle P-I,

représentent ou non le cas général du sol de bois nérophytique mediterranéen sur le substrat non calcaire.

Je ne suis pas partisant d'avancer des théories avant de connâitre les faits. Et la connaissance des faits exige commencer beaucoup de coupes, en rapport avec la connaissance géobotanique du pays, et étudier après les échantillons au laboratoire.

SCHEMATISCHE BODENKARTE DER IBERISCHEN HALBINSEL

Dr. P. Treitz

Auf der Karte sind zehn Bodentypen ausgeschieden. Das grosse Gebiet der braunen Walderde muss noch in einige Unterabteilungen geteilt werden, denn der Boden des tertiären Gebietes unterscheidet sich in allen Eigenschaften von den Böden dieser Zone, welche auf kristallinen kalklosen Gebirge und diese wieder von jenen, welches auf kalkigen Gestein liegen. Das Klima macht ausserdem auch noch Differenzen.

Der östliche Teil der Zone ist ausserordentlich trocken, der westliche Teil hingegen sehr feucht. Nicht nur die Menge der Niederschläge ist grösser, sondern auch die Luft ist während den grössten Teil des des Jahres viel feuchter. Beide klimatische Faktoren üben einen sehr tiefgreifenden Einfluss auf die Bodenbildung aus; in einer mehr detaillierten Bodenkarte muss ihnen Rechnung getragen werden.

In der Bodenkarte von E. Ramann sind die Skeletbödenregionen nicht ausgeschieden, sowie die Gelberden von den Braunerden auch nicht getrennt, endlich fehlt das äusserst interessante Gebiet der Halbwüste bei Murcia, welches das einzige Gebiet der echten afrikanischen Halbwüsten in Spanien darstellt.

Sehr wichtig sind die *roten Böden* der *Flussalluvionen.* Diese sind Produkte von eisenhältigen Wässern, welche in dem Flusstälern aus den Untergrund empordringen und den Boden mit Eisenoxid saturieren. Beim Austrocknen, während des Sommers erfährt das Eisen eine Oxidation und der Boden färbt sich intensiv rot. Solche Täler gibt es in allen Ländern und unter allen möglichen klimatischen Verhältnissen. Der Boden reichert sich in jedem Falle an Eisen an, nur die Farbe des Bodens wechselt je nach der Art des herrschenden Klimas, von blaugrau, über dunkel-braunrot bis zu indischrot. Bei Valencia haben wir ein ganz rotes Profil heben können, es ist der Boden eines Orange-Gartens. Ein Gärtner aus Kalifornien, den die spanische Regierung aus N.-Amerika kommen lies, erklärte, dass dieser Boden dem typischen kalifornischen Roterde-Boden gleich ist. Solche Böden finden sich in den Tälern fast aller Flüsse. Während der III. agrogeologischen Konferenz in Prag haben wir Gelegenheit gehabt solche Böden in dem Tale der Elbe vor

Kolin zu sehen. Wir konnten konstatieren, dass dieser Teil des Elbflusses auch in einem sich allmählig senkenden Gebiete liegt. (CO_2-Exhalationen) Auch in Russland habe ich ähnliche Böden in den Flusstälern gefunden. In Ungarn sind solche Böden an tektonischen Linien entlang überall zu finden. In Italien sind Böden ähnlicher Entstehung allgemein verbreitet. Ich glaube ein Teil der "Laterite" ist in diese Gruppe zu reihen.

TABELLE 1.—Mittlere Lufttemperatur in Norwegen 1841–1890

(Nach H. Mohn: Klimatabeller for Norge, Vidensk. selsk. skr. 1895)

	Höhe	Januar	April	Juli	Oktober	Jahr
	m. ü. M.					
Nördlicher Teil						
Sydvaranger	20	−10,7	−2,9	11,5	−0,1	−0,9
Alten	13	−8,0	−1,5	12,1	0,3	0,5
Tromsø	15	−3,0	−0,3	11,0	2,2	2,4
Lødingen	13	−1,9	0,7	12,5	3,6	3,6
Bodø	7	−1,6	1,7	12,6	4,1	4,1
Brønnøy	11	−0,3	3,1	12,8	5,6	5,2
Westlicher Teil						
Stenkjær	8	−3,6	2,6	14,2	4,3	4,2
Trondhjem	11	−2,6	3,3	14,0	5,1	4,7
Kristiansund	16	1,6	4,4	13,1	7,0	6,4
Aalesund	14	2,3	4,7	12,9	7,4	6,8
Bergen	17	1,2	5,6	14,4	7,3	7,0
Skudenes	4	2,1	5,3	13,9	8,5	7,4
Røldal	430	−4,5	1,6	13,0	3,6	3,5
Südlicher Teil						
Lindesnes	19	0,7	4,7	15,1	8,3	7,1
Kristiansand (Ek)	22	−1,0	4,6	15,8	7,1	6,5
Larvik	18	−2,4	4,3	16,2	6,3	5,9
Holmestrand	3	−2,9	4,3	16,7	6,2	5,9
Oslo	25	−4,4	4,4	17,0	5,5	5,5
Zentraler Teil						
Hamar	140	−7,9	2,4	15,2	3,7	3,1
Lillehammer	190	−7,9	2,7	15,3	2,6	3,2
Listad	277	−8,7	2,5	14,9	2,9	2,6
Dovre	643	−8,5	−0,4	11,9	0,8	0,8
Hjerkin	963	−8,2	−2,8	9,7	−0,5	−0,4
Tønset	498	−12,1	−0,1	12,6	0,4	0,0
Røros	630	−10,6	−1,9	11,2	0,2	−0,5

Salzseen und *Salzauswitterungen* kommen im ganzen Lande zerstreut vor, sie lassen sich weder mit Klima, noch mit orographischer Lage, noch mit Gestein in Verbindung bringen, sie sind einzig und allein mit dem tektonischen Aufbau des Geländes in Zusammenhang. Natürlich sind sie am meisten auffallend im Halbwüsten Klima. Der Boden um Murcia und Elche-Alicante u.s.w. ist fast überall salzig. Und die im Frühjahr

stagnierenden Wässer sind alle Salzteiche. Endlich kommen auch in Spanien an der Südküste von Barcelona bis Gibraltar überall *Salzlagunen* vor, welche eine ganz ähnliche Ausbildung haben, wie die Limane um das Schwarze Meer herum, oder die Lagunen um das Adriatische Meer herum, oder die berühmten Salzseen bie Arles am Delta der Rohne (Camargue Südfrankr.). Der berühmteste Salzsee ist der Albufer-See bei Valencia. Nicht nur das Wasser des Sees ist salzig, sondern auch der Boden um den See herum. Auf den Anhöhen finden wir hier den schon erwähnten *Roten-Tonbiden* der Flussalluvionen. Hier ist die Salzbildung, die Bildungender Salzseen, die Rotfärbung des Bodens, die Entstehung des Salzbodens schön und klar nebeneinander zu sehen. Der Boden ist nicht salzig.

Da das ganze Gebiet bewässert wird, so kann sich das Salz nicht anhäufen. Wenn er aber als Reisfeld benützt wird, so sammelt während der Vegetationszeit sich sehr viel Salz in ihm an und zwar meist Sulphate und Chloride.

Skeletboden und *Podsol* mit Rohhumus kommt in den nördlichen Gebirgen vor, wo das Klima sehr feucht ist und die Vegetation auch noch mit den mitteleuropäischen gleich ist. Es kommen hier noch wirkliche Heiden vor.

Podsol auf granitischen Gestein umgibt die hochen Gebirgsketten. Das Gestein ist dort noch mit einer Lage von feinkörnigen Boden bedeckt und es sollen schöne Wälder darauf blühen. Ich habe leider dieses Gebiet nicht gesehen nur Bilder und kenne sie nach der Beschreibung.

Braune Walderde bedeckt den grössten Teil des Landes so im Karst, wie auch in den mit wenig Erde bedeckten Zonen. Ich habe die braune Bodenzone in drei Teile geteilt, von welchen ich zweie einzeichnen konnte aber die dritte, den verkarsteten Teil, muss ich erst von Prof. Villar einzeichnen lassen, da er auch diese Gebiete mehrfach bereist hat.

Der interessanteste Teil ist der, wo die braune Walderde mit Terrarossa abwechselt. Das ist der Teil, der zwischen dem Flusse Quadalquivir und dem Meere liegt. Es ist ein gebirgiges Land mit vielen Salzseen in den Mulden. Auf den Hängen tritt überall dort Terrarossa, zu Tage wo die obere Decke denudiert wurde. Das ganze Land ist von einem sehr komplizierten geologischen Bau. Die einzelnen Etagen von Jura und Kreide stehen nebeneinander, oft ganz vertikal, so wie etwa in unseren Inselgebirgen Bakony, Vértes oder in dem Gebirge Mecsek bei Pécs (Fünfkirchen). Ich habe überall gefunden: ruhige Lage, keine Gesteinszersetzung; komplizierter geologischer Bau, Gesteinszersetzung auf Schritt und Tritt.

Gelberden sind echte Gebilde der Mediterranländer von Genua bis Gibraltar. Auch in Ungarn sind ähnliche Ablagerungen an der unteren Donau. Wo jährlich viel Flugstaub fällt, dort bedeckt Gelberde die Abhänge der Gebirge.

Gelberde mit Terrarossa. Die Terrarossabildung ist von der Gelberde unzertrennlich, von Genua bis Alicante (wahrscheinlich bis Gibraltar) finden wir in den zersetzten Teilen der Kalk und Dolomitgesteines Terrarossa. Die Abhänge der ruhig liegenden Dolomite und Kalk-

TABELLE 2.—Mittlere Niederschlagsmenge in Norwegen 1876–1910

(Nach Nedbørsiagtagelser i Norge, Tillægshefte til aargang XVIII, 1912)

	Höhe	Januar	April	Juli	Oktober	Jahr
	m. ü. M.	mm.	mm.	mm.	mm.	mm.
Nördlicher Teil						
Sydvaranger	18	18	15	65	38	375
Alten	7	23	11	55	27	304
Tromsø	38	119	59	63	113	1062
Svolvær	1	172	75	73	190	1435
Bodø	18	91	47	68	108	952
Brønnøy	6	87	45	69	108	916
Westlicher Teil						
Stenkjær	5	83	36	65	84	792
Trondhjem	34	112	55	70	111	958
Kristiansund	23	125	56	80	146	1160
Florø	2	233	104	140	248	2120
Lærdal	7	59	15	51	53	537
Bergen	20	219	95	153	237	2053
Stavanger	30	104	56	48	138	1076
Røldal	410	167	57	96	147	1381
Südlicher Teil						
Flekkefjord	4	181	107	105	178	1695
Kristiansand (Ek)	22	110	67	100	160	1250
Kragerø	19	59	58	97	134	998
Holmestrand	3	49	58	87	116	883
Oslo	23	26	34	74	69	587
Aas	84	42	44	83	94	759
Zentraler Teil						
Hamar	138	25	29	70	57	524
Lillehammer	189	31	37	73	69	629
Listad	317	15	14	64	39	399
Dovre	642	33	14	53	31	384
Hjerkin	953	12	9	57	18	293
Tønset	490	19	13	60	30	348
Røros	627	26	12	68	34	417

gesteine wird auf der ganzen Strecke von Gelberde bedeckt, sobald aber eine Aenderung des Gesteines eintritt, oder ein Bruch, Verschiebung oder Senkung, sogleich sind die Spalten und Risse mit Terrarossa ausgefüllt. Sowie auch die Höhlungen und Poren der Ablagerungen in den Talsohlen

meist Schotter, Gesteinschutt, oder ragt ein kleiner Riff von Spalten durchsetzt aus der Talsohle empor, so sind auch diese mit Terrarossa ausgefüllt.

Halbwüsten Boden. Im trockensten Gebiet der Iberischen Halbinsel finden wir die Gebirge ganz entblöst, nur ganz frisches Gestein auf der Oberfläche. Die Täler hingegen mit losen Materiale ausgefüllt. Alle Berge scheinen sich aus einer Ebene zu erheben. Der Boden der Täler ist meist kahl, nur xerophiles Gestrüpp kommen inselweise darin vor. Um Quellen und auf bewässerten Gebiete stehen Palmenoasen ganz wie in Afrika. Der Boden ist ein ganz heller rötlich-gelber, kalkiger Boden der Halbwüsten.

Steppen Boden Ohne Profil—Mancha.—Unterhalb Madrid verf achen die Hügel, es beginnt eine niedrigere Hügellandschaft mit ausgedehnten Plateauen. Die Flüsse haben schmale Täler eingeschnitten, welche mit steilen Wänden begrenzt sind. Endlich südlich vom Flusse Ebro verflacht sich das Gelände und wir erreichen das grosse Bassin, die Mancha. La Mancha ist eine wirkliche Steppe, ohne Steppenboden, die Oberfläche des Bodens wird fortwärend denudiert, es liegt meist das nakte Gestein zu Tage.

Bei Alkazar bildet den Boden Buntsandstein, wo er zersetzt ist, wird er gepflügt, wo er frisch ist, liegen die grossen Sandstein Platten horizontal und sind *ganz kahl.*

An den Salzseen herum kommt echter Salzboden vor, mit typischen Szikprofil. Ob in der Mitte von der La Mancha auch humoser Steppenboden vorkommt weiss ich nicht.

Wie sieht das Profil des Bodens aus zwischen Alkazar und Albacete muss Villar beschreiben.

Tierras Campos—hat, gelben Boden, nur mit sehr wenig Humus. Es ist ein lössähnliches Gestein, aber nicht so Gelb, mehr fahlockerfärbig. Aufschluss 4 m. einheitlicher Untergrund mit vielen Poren und schimmelartigen Kalkausscheidungen darin, auch kein echter Steppenboden.

SOLS DE LA REGION MÉDITERRANÉENNE DE LA FRANCE

DR. M. V. AGAFONOFF

Cette région est limitée à l'ouest par le Plateau Central au nord-est par les Alpes maritimes. Elle comprend toute la partie méridionale de la Vallée du Rhône jusqu'à Privat et Valence. C'est la région du climat méditerranéen (température annuelle moyenne de 13° à 15°; celle de l'hiver n'est jamais inférieure à 6°, et celle de l'été, à 21°; la quantité moyenne des eaux atmosphériques est de 500 à 785 mm.).

Les sols de cette région sont de teintes différentes, rouge, rouge-brun,

jaune, jaune-brun et gris; ils sont peu épais (de 10 à 50 cm.) grumeleux et contiennent presque toujours des particules plus ou moins grandes de la roche-mère. La quantité de l'humus y dépasse rarement un pour cent (le tableau du dosage de l'humus et de l'acide carbonique). pH de ces sols (méthode calorimétrique) varie entre 6,5 et 7,5 avec tendance à une faible alcalinité (7,5) plutôt qu'à une faible acidité (6,5).

La caractéristique de cette région est l'existence d'une grande quantité de sols rouges et rouge-bruns qui se sont fromés non-seulement sur des calcaires, ce que l'on rencontre aussi parfois dans d'autres régions de France, mais également sur d'autres roches, par exemple, sur des grès granitiques (Solliès = Pont, Var).

Le caractère général des sols de cette région est le fait que le processus podzolique (accumulation d'oxydes de fer et d'alumine dans les horizons moyens (B) et inférieurs (C)) se manifeste très faiblement et généralement se rencontre seulement dans les endroits bas. L'exemple nous en est fourni par le sol rouge-brun de Beaulieu, (Salliès-Pont, Var, analyse V A, V B, VC et V D), où le niveau de l'eau souterraine se trouve à 75 cm. de profondeur et où l'on renconte à partir de 10 cm. de la surface, des globules (de 1 à 2 mm.) noirâtres des hydroxydes de fer. Une accumulation des hydroxydes de fer et d'alumine moins importants encore (quelques dixièmes pour cent) se rencontre dans le sol calcaire gris du champ d'expériences de la Station agronomique d'Avignon (IV A et IV B). Enfin dans le sol jaune-brun des environs de Montpellier (voir analyses I A et I B), l'on observe une accumulation insignifiante d'oxydes de fer dans l'horizon B, tandis que la quantité d'oxyde d'alumine dans cet horizon est moindre que dans l'horizon A.

Dans les sols rouges, rouges-bruns et rouges-jaunes-bruns de cette région méditerranéenne de la France, formés sur des calcaires d'âges géologiques différents, l'on peut parfois rencontrer dans les parties inférieures de l'horizon B des couches de concrétions calcaires enrichies de carbonates (de 16,56% à 31,46 % CO_2); l'horizon B est dans ce cas relativement appauvri en carbonates Tableau 2. Ces concrétions sont parfois d'un jaune-brun (Port-de-Bouc, Montpellier-Mendon), parfois d'un rouge-brun (Menton, Cap Martin).

L'analyse chimique des concrétions de Montpellier-Mendon (Tableau 1, I B′) montre avec évidence que ces concrétions se sont formées des sables de Montpellier (pliocène, Tableau 1 I C) enrichis par des infiltrations de l'horizon supérieur B (Tableau 1 I B). L'examen microscopique de ces concrétions et du sable de Montpellier sousjacent met en évidence une composition minéralogique presque identique: tous deux sont composés de débris de grains de quartz et de calcite soudés plus ou moins par un ciment ferro-calcique; rarement l'on y rencontre des grains de feldspath, de muscovite, de biotite et de l'épidote. La structure microscopique et la composition minéralogique du sable de Montpellier se rapprochent

beaucoup de celles du calcaire rouge assez friable (de plusieurs dizaines de mètres d'épaisseur) sur lequel se sont formés les sols rouges-jaunes des environs de Port-de-Bouc (St. Jean); la teneur de ces calcaires en CO_2 (10,8%) et la perte au feu (4,43%) les rapprochent également du sable de Montpellier (Tableau 1 I C et Tableau 2), ce qui permet de supposer que leur âge est le même (pliocène).

La présence de ces concrétions calcaires indique que pendant la formation de ces sols il y a eu une période d'un climat plus sec (de steppes ou demi-désertique), qui a probablement varié plusieurs fois avant d'aboutir au climat actuel plus humide.

TABLEAU 1.—Analyses Chimiques [a]

	I_A	I_B	I_B'	I_C	II_A	III_A	III_C	IV_A	IV_B	VI_A	VI_B	VI_C	VI_D
SiO_2	71.90	72.70	45.65	57.65	88.10	8.86	2.54	39.16	40.24	72.04	68.00	65.16	72.68
Al_2O_3	9.66	8.90	5.50	5.78	4.10	2.52	0.39	7.59	8.08	12.32	14.73	16.67	15.15
Fe_2O_3	3.99	5.01	3.44	2.87	2.76	0.63	0.16	1.81	2.14	2.71	3.50	3.94	2.36
FeO						0.19	0.05	1.21	1.06	0.45	0.45	0.41	0.41
MgO	0.09	0.09	0.11	0.08	0.03	néant	0.07	1.18	0.93	0.21	0.55	0.51	0.07
CaO	2.81	2.38	22.43	15.12	0.77	47.44	53.88	22.72	22.82	0.98	0.92	0.78	0.62
Na_2O	1.18	0.96	1.04	1.30	0.29	0.45	0.38	0.83	0.89	3.51	3.08	5.72	6.95
K_2O	0.90	0.83	0.89	0.99	0.77	0.09	0.11	1.26	1.26	1.55	1.57	1.49	0.53
TiO_2						0.11	néant	0.32	0.40	0.50	0.62	0.61	0.52
P_2O_5						traces	traces	0.21	0.17	0.07	0.06	0.06	0.11
Perte à 105°	6.52	7.34	4.05	4.05	2.62	1.56	0.41	1.84	1.62	2.75	3.50	2.17	0.32
Perte au rouge						1.52	0.55	6.28	4.33	3.08	2.97	2.41	0.61
MnO	0.34	0.25	traces	0.08	0.29	0.03	0.03	0.13	0.13	0.10	0.11	0.06	0.04
CO_2	2.27	0.91	16.56	11.85	0.10	36.76	41.50	15.82	15.92	néant	néant	néant	néant
Cl						0.05	0.04						
SO_3						néant	néant						
	99.66	99.37	99.67	99.80	99.73	100.01	100.11	100.36	99.99	100.27	100.06	99.99	100.37

[a] Ces analyses sont faite par M. Pichard de l'Institut des recherches agronomique et A. Raoult; je les remercie chaleureusement. V.A.

La présence des concrétions calcaires *rouges* (teintées par des hydroxydes de fer), que l'on trouve, par exemple, dans l'horizon B des sols rouges du Cap Martin (Menton), n'indique-t-elle pas que le climat plus sec de la période de formation de concrétions purement calcaires, sans coloration rouge, aurait été remplacé dans la suite par un climat si humide qu'il permit l'infiltration des oxydes de fer dans les couches inférieures où ils auraient coloré les concrétions antérieurement formées.

La présence des sols rouges qui ne renferment ni concrétions calcaires, ni carbonates en général (Fort Mont-Alban, Villefranche) montre que dans cette région le processus de décalcification a été total. Cette supposition est également confirmée par un développement extrême de zones transparentes d'accroissement dans les grains de calcaire dolomitique jurassique d'où proviennent les sols rouges du Fort Mont-Alban. (Ces zones d'accroissement se sont formées à partir du ciment calcaire actuellement disparu).

La transformation du calcaire jurassique grisâtre relativement pur (Grabels à 15 Km. au nord-ouest de Montpellier) en calcaire rouge qui forme sur lui une couche mince, particulièrement développée dans les

TABLEAU 2.—Dosages de l'humus méthode Simon et de CO_2

Localités et les horizont	Humus	CO_2
Port de Bouc (St. Jean)		
Horizon A	0.66	12.36
Do B	non dosé	21.06
Concrétions B'	Do	31.46
Horizon D	Do	10.80
(Calcaire rouge)		
Mazargues (près de Marseille)		
Horizon A	0.26	11.61
Do B		8.81
Breche de Mazargue		32.35
Avignon		
II. Villeneuves des Avigno horizon A	1.08	11.18
II. Do N. C. (mollasse)		11.21
III. A (sur diluv. alpin)	1.75	3.18
III. (B+C) (diluv. alpin)		1.11
Montpellier Mendon. Horizon A	0.51	2.27
Do Change d'experience—A (sur diluv. alpin)	0.85	0.10
Menton Cap. Martin		
Horizon A	5.41	6.00
Do B	5.40	0.47
Concrétions B'		30.25
Horizon C		40.50
(Calc. parassifue)		
Ville Franche. St. Hospice Cap. Ferrat		
Horizon A	5.54	13.04
Do B		14.48
Do C (Calcaire crètuefue)		35.34
Fort Mont-Alban		
Horizon C (calc. jurass)		44.70
Solus-Pont Beautui (Var.)		
Horizon A	1.51	Néant

fissures, est très nettement représentée par deux analyses—III A (calcaire jurassique primitif) et III C (produit rouge de la décomposition du III A).

Dans ces deux analyses, il est intéressant de signaler la teneur en alcalis, qui reste presque stationnaire durant toute la période de décomposition

chimique de la roche-mère calcaire. L'on observe le même phénomène dans les analyses d'autres sols calcaires de la région méditerranéenne et de leurs roches-mères calcaires (anal. I, III, IV).

Le processus de formation des sols consiste ici essentiellement dans la décalcification, dans l'accumulation de quartz, et dans la formation d'alumo-silicates hydratés.

Il faut remarquer que les calcaires de la région méditerranéenne de la France ne forment pas toujours des sols rouges, rouges-bruns et rouges-jaunes-bruns; il se forme parfois sur ces roches des sols calcaires brun-grisâtres compacts et durs, comme le sont, par exemple, ceux de la Station Agronomique Expérimentale d'Avignon (aux environs d'Avignon—Anal. IV A et IV B), des sols gris-verdâtres sur des molasses marines helvetiennes (Villeneuves des Avignons, à 2 Km. à l'Ouest d'Avignon), des sols gris friables sur des brèches calcaires de Massargues (environs de Marseille), des sols friables jaunes-brunâtres, riches en carbonates et contenant de nombreuses particules de la roche-mère sur les calcaires crétaciques blanc-jaunâtres à St. Hospice (St. Jean, Cap Ferrat), et beaucoup d'autres sols.

Les différences qui existent entre ces divers sols sont dues en partie à leur formation sur des roches-mères de natures différentes; mais il me semble qu'il faut surtout en chercher la cause dans leur élaboration à des époques géologiques différentes, aux climats différents; ces caractères divers n'ont pas pu s'effacer totalement même au moment où tous ces sols se trouvèrent sous le même climat méditérranéen actuel. Seules des recherches ultérieures et détaillées pourront élucider cette question qui n'intéresserait pas seulement les pédologues.

Les sols rouges-bruns peuvent se former dans la région méditérranéenne non seulement sur des calcaires, mais aussi sur d'autres roches-mères. Tel est le sol rouge-brun formé sur une arcose granitique à Beaulieu, à Solliès-Pont, Var (Voir les analyses V A, V B, V C et V D). La décomposition chimique de la roche-mère présente ici un caractère différent de celui des roches calcaires. Il se produit une accumulation de potassium, une diminution de sodium, une faible mai graduelle augmentation de calcium, une diminution de silicon et de aluminium; une certaine augmentation d'aluminium et de fer dans l'horizon C est dûe probablement aux processus podzoliques secondaires; une augmentation progressive de la perte au feu, partant de la roche-mère vers l'horizon A s'explique par une accumulation d'alumo-silicates hydratés.

J'ai pu entreprendre les excursions pèdologiques nécessaires à l'exécution de ce travail grâce à l'intervention généreuse de l'Institut des recherches agronomiques et je tiens à adresser tout particulièrement à M. E. Roux, Directeur de cet Institut, et M. A. Bruno, inspecteur général, mes bien vifs remerciements.

The action taken by Subcommission III at the Congress meetings in Washington, D. C., was reported by Dr. Stremme as follows:

SITZUNGEN DER UNTERKOMMISSION FÜR DIE BODENKARTE EUROPAS IN WASHINGTON, D. C., AM 14. UND AM 16. JUNI, 1927

Anwesend die Herren Glinka, Polynov, Jarilov, Wolff, Krische, Hohensheim, Marbut, Björlykke, Saidel, Treitz, Ogg, Robinson, Miklaszewski, Stremme.

Der Vorsitzende Stremme legt die inzwischen veröffentlichte Bodenkarte Europas vor und erläutert die zukünftigen Arbeiten. Es wird beschlossen, den von der Druckerei angebotenen Neudruck der Karte anzunehmen und in diesen alle gegenwärtig gewünschten sachlichen Verbesserungen aufzunehmen. Je etwa 400–500 der neuen Karte kommen mit einem französischen Text durch Herr Miklaszewski und einem englischen durchdie Herren Ogg und Robinson versehen und diese an die französisch und englisch sprechenden Mitglieder der Gesellschaft versandt werden. Die Kosten der neuen Texte werden nicht von der Kommission getragen.

Sodann wird Geschlossen, das Angebot des Gea Verlages, Berlin, anzunehmen, nach welchem eine neue Karte im Masstabe 1:2,500,000, in Farben ausgeführt und mit einer etwa 40 Druckbogen starken Erläuterung versehen, im Laufe der nächsten drei Jahre bis zum Kongress in Russland fertig gestellt werden soll. Zur Förderung der Arbeit soll der Präsident der bodenkundlichen Gesellschaft gebeten werden, die Regierungen der europäischen Staaten um tatkräftige Förderung zu besuchen. Die Herren Miklaszewski, Robinson und Wolff erklären sich bereit, je einen französischen, englischen und deutschen Text der Addresse an die Regierungen herzustellen. Es wird zur Kenntnis genommen, dass der Verlag die Karte zu einem Subskriptionspreise von 100 bis 130 Goldmark an die Mitglieder der Gesellschaft abzugeben bereit sein wird.

Nachträge

1. Der Präsident Dr. Lipman legt dem Vorstand der Gesellschaft einen Plan vor, für eine Bodenkarte der gesamten Erde auf 10 Jahre je $50,000 zu sammeln. Für die Aufnahme, Zeichnung und Redaktion der Bodenkarte Europas würde nach der Feststellung Dr. Stremmes ein Betrag von $100,000 notwendig sein.

2. Am 22. Juni wurde in der Vollversammlung der V Kommission der bisherige Vorsitzende der Unterkommission Prof. Dr. Stremme wiedergewählt.

3. Während der Überlandexkursion vom 22. Juni bis 22. Juli wird die Frage der Analysenbeigabe von den Mitgliedern der Unterkommission mit den. Vorständen der chemischen und physikalischen Kommis-

sion und der grossen Laboratorien besprochen. Es wird empfohlen, von chemischen Analysen in erster Linie die Vollanalyse von mehreren Horizonten der Bodenprofile für die zukünftige Karte ausführen zu lassen. Daneben sind beliebig viele andere chemische, ferner physikalische und biologische Untersuchungen der Profile erwünscht.

Dr. W. Wolff, Secretary of Subcommission III, submitted the following paper in connection with the work of this Commission:

REPORT OF SUBCOMMISSION III

Dr. W. Wolff, Secretary

In welchem Mass kann die Geologie des Muttergesteins als Grundlage für die Scheidung der Böden in Einheiten oder Gruppen von Einheiten dienen?

Der Ausdruck "Geologie" is sehr vielseitig. Er umfasst das Alter, die Entstehung, die petrographische Beschaffenheit, die Lagerungsweise, die Struktur, die Tektonik, die regionale Verbreitung und zahlreiche andere Eigenschaften eines Gesteins. Jede dieser Eigenschaften kann unter Umständen für das Gestein als Element der Bodenbildung eine geringere oder grössere Bedeutung besitzen. Nehmen wir z. B. das Alter. In Norddeutschland gibt es ausgebreitete diluviale Grundmoränen aus Geschiebelehm. Ein Teil von ihnen gehört der jüngsten Vergletscherung an, die auf die weitere Umgebung des Ostseebeckens beschränkt blieb. Es handelt sich hier um Geschiebemergel mit einem Kalkkarbonatgehalt von 10–40 Prozent und einem Alter von schätzungsweise 15–20000 Jahren. Dieses Alter ist gross genug, um die Ausbildung reifer Bodenprofile—es handelt sich überwiegend um podoslige Böden und braune Waldboden—zu ermöglichen, aber nicht gross genug, um die Prozesse der Bodenbildung, insbesondere die Auslaugung, bis zu ihrem grössten möglichen Umfang durchzuführen. Letzteres ist unter vielfach ganz denselben klimatischen Bedingungen bei den älteren Grundmoränen geschehen, die ausserhalb des Gebietes der jüngeren zutage liegen und ursprünglich dieselbe chemisch-petrographische und physikalische Beschaffenheit gehabt haben wie diese. Infolgedessen findet man innerhalb einer und derselben klimatischen Bodenzone, z. B. im Westen und Nordosten von Hamburg, recht vershiedenartige Böden auf Geschiebemergel, je nach dessen Alter. Auf dem jungen Geschiebemergel im Nordosten ist der Horizont C schon in 1–1.5 m. Tiefe zu erreichen, auf dem alten Geschiebemergel im Westen erst bei 1.5–3 m. Tiefe. Der Horizont A ist bei ersteren gewöhnlich reicher an Feinerde bezw. Ton als bei letzteren. Auf Sandböden sind die Unterschiede noch viel grösser. Für die Landund Forstwirtschaft ist das von sehr grosser Bedeutung.

Auch die Entstehung eines Gesteins kann auf die Bodenbildung Einfluss haben. Bei Gerona im nordwestlichen Spanien habe ich eozäne Gesteine marinen und fluviatilen Ursprungs gesehn. Die marinen Mergel waren kalkhaltig, tonig und gaben einen frischen, mineralkräftigen C-Horizont ab; die fluviatilen oder lacustren dagegen bestanden aus stark oxydierten und ausgelaugten Materialien von rötlicher Färbung, auf denen sich dann auch rote, weniger fruchtbare Böden entwickelten. Die fluviatilen Ablagerungen des Tertiärs sind auch in Deutschland, besonders in den norddeutschen Braunkohlenrevieren, sehr basenarm und unterliegen daher einer viel durchgreifender en Auslaugung als die marinen Ablagerungen.

Über die Bedeutung der Struktur und der petrographischen Beschaffenheit für die Bodenbildung brauche ich mich nicht weiter auszusprechen. Ich erinnere nur an den Löss, der vermöge seiner Porosität und seines Kalkgehaltes die Schwarzerdegrenze nicht unbedeutend gegen das humide Klima zu verschieben vermag, oder an die Unterschiede der Bodenbildung auf Apliten und auf grobkörnigeren, feldspatreicheren Graniten.

Was die Tektonik betrifft, so hat in neuerer Zeit P. Treitz darauf aufmerksam gemacht, dass tektonisch gestörte Gesteine oft in erheblichem Mass von CO_2-Exhalationen betroffen und verändert werden. Auf der Studienreise in Ungarn im August 1926 lernten wir bei Sopron derartige Erscheinungen kennen.

Am stärksten kommt die Geologie der Gesteine bei den "Ortsböden" im Sinne Ramanns zum Ausdruck. Hier decken sich unter Umständen Bodenart und Bodentyp, z. B. bei den Mooren, Marschen und Dünen. Bekannt ist ja auch die besondere bodenbildende Wirkung der Kalkgesteine und des Gipses.

Grundsätzlich ist allerdings die Gesteinsart nur Objekt, nicht Faktor der Bodenbildung. Die massgebenden Faktoren sind vielmehr rein klimatischer und vegetativer Art, in erster Linie Temperatur, Verdunstung und vorwaltende ab- oder aufsteigende Wasserbewegung. Sie bestimmen bei dem fruchtbarsten Klassifikationsprinzip, dem *genetischen*, die wissenschaftliche Einteilung der Böden. In zweiter Linie aber muss die Substanz, die das Objekts der Bodenbildung ist, mit ihrem ganzen Reichtum an chemischen und physikalischen Eigenschaften in Betrachtung gezogen werden. Dies ist ganz besonders der Fall, wenn die Gliederung der Böden zum Zwecke kartographischer Darstellungen vorgenommen werden soll.

Hierbei sind zu unterscheiden: Übersichtskarten grosser Gebiete in kleinem Masstab, Übersichtskarten in grösseren Masstaben und Spezialkarten.

Bei den Übersichtskarten grosser Gebiete in kleinem Masstab, wie z. B. bei der nunmehr fertiggestellten allgemeinen Bodenkarte von

Europa in 1: 10,000,000, ist eine Berücksichtigung der Gesteinsarten gewöhnlich nicht möglich, weil ihre Verteilung zu kompliziert ist.

Bei den Übersichtskarten in grösseren Masstäben, z. B. bei der in Arbeit befindlichen Bodenkarte von Deutschland in 1: 1,500,000 müssen die Gesteinsformationen in grosse petrographische Gruppen unter Berücksichtigung ihrer bodenbildenden Eigenschaften zusammengefasst werden. Die Einteilung ist dann bis zu einem gewissen Grade eine Frage der Zweckmässigkeit und der Besonderheiten des darzustellenden Gebietes. Geeignete Gruppen sind z. B:

saure } Eruptivgesteine bezw. krystalline Gesteine
basische }
Quartzite
Sandsteine mit silikatischem
" " tonigem oder kalkigem Bindemittel
Grauwacken, Arkosen
Schiefer
Tone
Lehme, Tuffe
Mergel und Mergelschiefer
Kalkgesteine
Staubgesteine
Sande, Kiese, Aschen.

Bei den Spezialkarten sollen die Gesteinsarten hinsichtlich aller bodenbildenden Eigenschaften in stärkstem Masse berücksichtigt werden. Hier spielt z. B. die Körnung der Sande, ihr gehalt in Kalkkarbonat, Feldspat usw. eine grosse Rolle, besonders wenn es sich um Bodenkarten zum Nutzen der Land- und Forstwirtschaft handelt. Eine Normalgliederung ist hier nicht mehr zweckmässig, vielmehr muss die Gliederung stets an den örtlichen Besonderheiten entwickelt werden.

The fifth subcommission of Commission V was organized in Washington, during the meetings of the Congress. The resolution effecting this organization is given on page 345 with the minutes of their first meeting.

Dr. A. A. J. de'Sigmond, Chairman of Subcommission IV, presented a general discussion of the subject of this Commission:

SUBCOMMISSION IV

THE CLASSIFICATION OF ALKALI AND SALTY SOILS

General Discussion of the Subject of the Subcommission on Alkali Soils

DR. A. A. J. DE'SIGMOND, Chairman

At the Fourth International Conference of Soil Science at Rome 1924, at the session of Commission II, Prof. N. Gangulee, University of Calcutta, India, suggested the appointment of a special committee to consider the problems of alkali investigations, both from a scientific and practical point of view. As this subject fell more in the field of Commission V, as chairman of Commission II I communicated with the chairman of Commission V, Dr. C. F. Marbut. He requested that I organize the Alkali Subcommission as a special Subcommission of Commission V.

This is the brief history of our Subcommission and I take pleasure in welcoming here the members of the new Subcommission upon the occasion of our first meeting.

As we see by the program of Subcommission III the material to be presented is very worthy indeed, proving that the proposition of Prof. Gangulee coincided with the spirit of the scientists engaged in Alkali Investigations and as chairman of the Subcommission, appointed by the chairman of Commission V, I am very glad indeed to see the interest in this line of work of the most distinguished scientific men in Soil Science and especially on alkali soils. In order to carry out the business of the organization I have asked Prof. Dr. Robert Ballenegger to act as secretary of the Subcommission, and further organization will take place at the meeting of the Congress.

In starting our work it seems practical to fix first the outlines of the subject which we might discuss in this Subcommission.

The old master on alkali reclamation, the late Prof. E. W. Hilgard, divided the salty soils in two genetic groups, the littoral and the terrestrial salty soils. The former are products of the effect of sea water on soils flooded by the sea, whereas the alkali soils are the products of insufficient rainfall and intense evaporation; that is to say the alkalis have their origin in climatic factors, the salty soils of the sea and other similar salty soils are connected with local salty sources such as sea water or other salt deposits. Therefore, the latter are not bound to any definite climate, they may occur in an humid or an arid climate; whereas, the alkali soils, as defined by Hilgard, occur only in a semi-arid or an arid climate and their origin is associated with a dry climate.

As long as the school of Hilgard dominated, Soil Science as regards alkali soils has almost generally accepted the theory that the very difference between the alkali soils and other soils of a dry climate consists only in the water-soluble salt content of the alkali soils, which salt was absent in non-alkali soils. My recent studies, combined with those of K. K. Gedroiz, J. S. Joffe, H. C. McLean, W. P. Kelley, and C. S. Scofield have given numerous evidences which prove that the main difference lies deeper, namely in the composition of the absorbing complex, or zeolite-humus-complex, of the soil. It is already evident, that in the case of normal arid or simi-arid soils, such as the black prairie soils, or chernozems, the zeolite-humus-complex is almost saturated—as high as 80 per cent—with Ca-cations and the rest chiefly Mg-cations, leaving only some insignificant portion of 8 to 10 per cent to the alkali cations (K and Na). In the case of alkali soils, on the contrary, we find, that the dominant rôle of calcium cations in the zeolite-humus-complex is more or less substituted or completely annihilated by the sodium cations; sometimes accompanied by potassium cations or magnesium cations. The investigations of the above cited authors prove also, that this characteristic change in the composition of the absorbing complex of the soil is due to the base-exchange which took place in the soil between the concentrated solution of water-soluble salts in alkali soils and the original absorbing complex of the soil. A glance at the figures of Table 1 will illustrate with a single instance, how the sodium salts of the "Szik" soil (alkali soil) of Hortobágy (Hungary) have gradually substituted Ca-cations in the surface horizon. The best way to show these changes is to give the exchangeable cations in per cents of the total taken as 100.

TABLE 1.—Exchangeable cations of alkali soil

Horizon No.	Exchangeable cations in per cent of the total (100)			
	Ca	Mg	K	Na
1	26.4	13.5	4.3	55.8
2	12.1	42.5	29.4	16.0
3	32.8	54.0	2.0	11.2
4	77.1	20.0		2.9
5	61.9	36.8	1.0	0.3
6	79.7	15.8	3.9	0.6

Further details are given in my paper, "Contribution to the Theory of the Origin of Alkali Soils" (11). Since that time I have investigated, in the Soil Laboratory of the Hungarian Royal Joseph-University of Technical Sciences, other alkali profiles reported in my paper, "The Chemical Characteristics of Soil-Leaching." M. A. Arany, Debrecen, (Hungary), my distinguished pupil, did the same, with about the same

general results (1). In Table 2 are reproduced the respective data of his researches concerning the alkali soil of Karcag, Hungary.

TABLE 2.—Exchangeable cations of Karag alkali soil

Horizon	Exchangeable cations in per cent of the total (100)			
	Ca	Mg	K	Na
cm.				
18a 0–20	26.149	13.304	3.796	56.751
19a 20–40	29.233	16.561	2.416	81.790
20a 40–60	34.775	15.289	0.943	48.993
21a 60–80	37.745	36.513	2.001	23.741
22 80–100	36.691	47.206	1.190	15.013

Consequently I feel entitled to state that this characteristic of the alkali soils is a more stable one than the water-soluble salt-content which Hilgard's school has emphasized during the last 25 to 30 years. Because, if the salt of the alkali soils has been washed out, and there was no opportunity to exchange the Na-cations too, then we will get very heavy clayey alkali soils, unproductive not because of their noxious salts but on account of the bad physical properties of the soil. In Hungary we have plenty of this type of soil, and from the papers of Gedroiz, I may suppose that the Soloti-soils in Russia are of about a similar character (2). Scofield is reporting on similar experiments made upon American irrigated alkali soils (10). Kelley published evidences of American alkali soils in which the exchangeable calcium and magnesium cations were completely absent (4).

But we now find a remark in the paper of Hissink, treating the exchangeable cations in some polders flooded with sea water, where he has found considerable exchangeable Na-cations, and the "Kwelder"-soils of Holland are similar sodium clay-soils (5), although not dependent on climatic conditions. This fact seems to again unite the two types of salty soils subdivided by Hilgard. It may be useful, on both sides, to the investigators if they could cooperate in similar methods of investigation.

For that reason we should consider and discuss; first, the fundamental question as regards the limits of our field of research. Would it not be better to enlarge our sphere of activity to include all kinds of salty soils or should we keep strictly to the alkali soils proper, in the sense as used by Hilgard?

However, as the Russian scientists are treating the alkali soils, and also in recent American publications we very often find the saline and alkaline soil terminology intermixed, I think it indicates that the field of this Subcommission should be enlarged to include all salty soils, in the

broader sense of the term, grouping then the different types of salty soils according to the principles given under (B). Since Commission V adopts genetic classification as a basis, which I also favor, before outlining the grouping and classification of salty soils in this broader sense, I feel it is necessary to summarize briefly the general genetic factors of the salty and alkali soils.

(A) General Factors in the Formation of the Salty and Alkali Soils

The first general factor of the formation of salty soils, using the term in a broad sense, undoubtedly consists in the permanent or temporary accumulation of water-soluble salts in the soil. The source of these salts may be very different varying according to local circumstances; nevertheless, we may divide them into two main groups: Salt accumulations in arid or semi-arid climate and salt accumulations in humid climate.

In arid or semi-arid climate the accumulation of water-soluble salts in the soil is due in the first place to the dry climate and to insufficient drainage. In most cases we can trace three factors responsible for the accumulation of salts in arid or semi-arid climate; namely, (1) The arid or semi-arid climate itself; (2) An impervious subsoil or hardpan; (3) Temporary abundance of humidity in the soil, interspersed with dry periods. Details of the evidences, which support this opinion, have been published in my paper cited above (1); and in my monograph on the Hungarian alkali soils (12) we may find further evidences. Theoretically I can imagine, that in a very arid climate the second condition can be neglected. Because the water evaporation (combined with soil capillarity) might be so rapid that the temporary abundance of soil humidity rises more quickly in the surface-horizon than can be drained off. But also in this case the third condition, the temporary abundance of soil humidity, is necessary, because unless there is abundance of water in the soil, the water-soluble salts cannot move or accumulate. This abundance of soil humidity may result not exclusively through precipitation water, but in most cases from seepage water and the rise of underground water.

Here we might also include some prehistoric literal salty soils now under arid climate, in which case the source of the salt accumulation may be ascribed to previous sea water, which previously flooded or swamped the present continental or dry basin.

In a humid climate under similar conditions we get peaty or boggy soils, which may be salty to some extent, but on account of the permanent abundance of water the salty character of the soil cannot develop unless we artificially cut off the sea water supplement, by diking the soil, as in the case of the polders in Holland, or by natural building of littoral deltas, as in southern France in the Camargue, or in upper Italy in the lagoons of the Pau. But we get similar salty soils in the environment

of some continental saline deposits, like in Transylvania, where the seepage water of the salt mine impregnated the surrounding soil with common salt. In all these cases the determining factor of the salty soil is not the climate, but local salty sources, salt wells, etc., which if excluded would enable the salty soil to change very rapidly into normal soil. That is not the case with the salty soils of an arid climate, the so-called alkali soils.

In the formation of alkali soils we may distinguish four steps of development:

(1) Salinization.
(2) Alkalization.
(3) Desalinization.
(4) Solotization or degradation of alkali soils.

In the scheme of Gedroiz (2) the salinization and alkalization are treated under one heading. But we can imagine circumstances under which only the salinization took place, giving no chance for alkalization. These are common salty soils like those of most of the humid climate in which the conditions did not favor the entrance of the cations of the soluble salts through base exchange in the absorbing complex of the soil. We know that this depends upon the concentration, quality and relative quantity of the different cations present in the soil and soil solution.

But if the relative concentration of the cations in the soil solution is sufficiently different from that in the absorbing complex of the soil, the displacement of those cations takes place in which the relative concentration is high in the absorbing-complex and relatively low in the soil solution. For instance, in most soil types of a semi-arid or an arid climate the dominant cation in the absorbing complex is the calcium cation. If for some reason or other, this type of soil is permeated with a solution rich in sodium salts, the sodium cation will displace the calcium cation from the absorbing-complex until by gradual increase of the calcium cations in the soil solution and decrease in the absorbing-complex, along with the reverse changes of sodium cations, an equilibrium is established. This process we may call alkalization because in the most recent cases alkali salts occur in practically most cases where alkali soils are developed. The degree of alkalization may be very different and can be determined by the rate of alkali equivalents in the total equivalents of exchangeable cations. During the alkalization process naturally the soil must be saline to a high degree, otherwise the process will hardly be complete. Nevertheless, we can suppose also, that a dilute salt solution is percolating permanently through the soil, and as we have evidences, that in this case some cation exchange has been noticed; now during a longer lapse of time, it is possible that sodium can enter in the absorbing-complex, although the amount in the soil may not be very high.

As very often these saline territories, already more or less alkalized, are frequently flooded or water lodged fields opportunity is given for desalinization; and by this the evolution of the alkali soil reaches the third place, that is the gradual leaching out of water-soluble salts. This desalinization can be done artificially too as in the case when we reclaim the alkali soils by irrigation and drainage. The washing out of the alkali salts will succeed or not according to the character of the alkalization of the absorbing-complex and the presence or absence of soluble or latent calcium cations in the soils. In the former case, the alkali soil will revert to normal soil in which the calcium cation will enter again, as the humus-zeolite-complex and the soil will become desalinized and have good physical properties. In this case and only in this case, will the artificial desalinization of the soil be successful. The evidence, especially those of Scofield (10) and of Kelley (7) prove this theoretical consideration and are in full accord with statements of Gedroiz.

During the desalinization, when the concentration of sodium cations in solution is appreciably advanced, another process of interchange will take place too. This process consists of the hydrolysis of the alkali-zeolite and humus complex and a gradual replacement of alkali cations, especially sodium cations by hydrogen, unless the alkali soil is rich in $CaCO_3$. Gedroiz calls this degradation process of alkali soils "solotization" and the soils "Soloti" soils. We have an abundance of them in Hungary and they can be reclaimed easily by a suitable liming process. These soils are as a rule completely deficient in $CaCO_3$ and their actual reaction often runs around a pH of 6, or even less. Consequently they are in a proper sense acid, and as I have demonstrated in my paper on the chemical characteristics of soil-leaching, presented to the Congress, they are considerably unsaturated. This was also proven by Arany.

(B) Introduction of General Principles of Soil Grouping and Classification

I am aware of the difficulties in introducing general principles of soil grouping and classification for the manifold circumstances and very varied, almost local, types of salty soils. The soil experts, who are engaged in the research of the different occurrence of these soil types, are familiar with the great variation in the local occurrence of the salty soils, and it is also hardly to be supposed, that the local terms or somewhat generalized names of one country could be substituted by new ones. But, on the other hand, if we intend to utilize the results of other countries in our own studies we must have a common basis through which we can understand each other. The black- or white-alkali, the types as pecos-, fersno-, Salt-Lake especially Billings-alkali type, may have some local value in the grouping of the alkali soils of the United States, the "solonetz," "solonchak" and "soloti" in Russia, "Reh," "Kalar" and its subtypes in some

parts of India, the "szik," "szek" and their different variations in Hungary, etc. But we are in need of a group and class based on general principles, which can be understood in America as well as in Europe, or India, or Egypt, Australia and so on. And the only general principle, which seems to me reliable and of an international character for such a group or class, lies in the general factors of the formation of these different salty soils and in their characteristic chemical, physical and biological properties. This general grouping must be built upon such general principles, which do not exclude the insertion of all the special local varieties and terms, but which enables just by this general character of the grouping the right understanding of the different local definitions and descriptions.

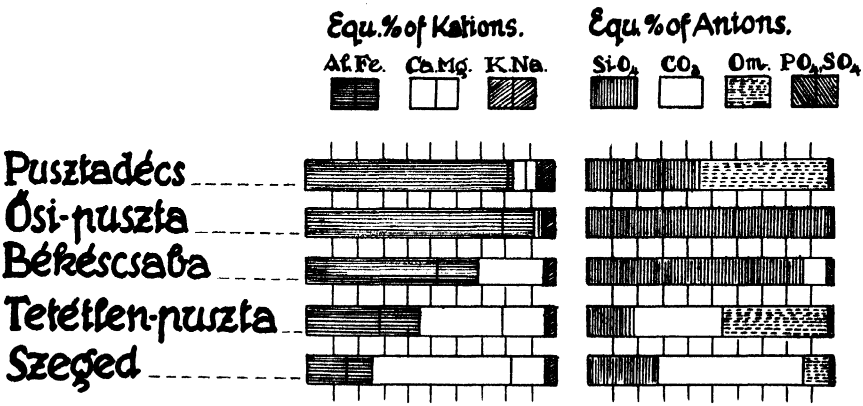

FIGURE 1.—Chemical characteristics of Hungarian alkali soils

The most general principle seems to me the above treated genetic differentiation. In the first place we should divide the salty soils into two main groups: The salty soils of humid or arid climate. But this is not enough as regards the climatic factor. We must go further in both climatic main groups. We know, according to Koppen (9), that in a humid climate we treat two zones: The zone of Briochore, or the Tundras, and the zone of Dendrochore, or forests (Podsol-zone). But the latter has different subtypes according to the average yearly temperature.

By this means, the arid climate is separated into two zones: That of the grassfields (Poechore) like the prairies in North America, the pampas in South America, the tshernozem or step-zone in Russia and our steps in Hungary. The other is the desert zone. Here again we are treating different subtypes. I do not feel that it is possible now to exactly establish those climatic zones, which are predominant in some salty soil type. I only want to illustrate, for instance, that up to the present I could not find any alkali soil in Hungary in which the calcium and magnesium cations were completely excluded by the absorbing complex; like in some

alkali soils found by Kelley (5). Probably this corresponds with the different climatic conditions.

The second principle of a general grouping may be the general chemical character of the soil. For instance, in Hungary, we have two distinct types of alkali soils. The one is relatively poor in calcium and magnesium but rich in aluminum and iron cations, in the other type we find the opposite. We find the same antagonism as regards the anions. In the former soils the CO_3 is absent or relatively low, and the SiO_4, that is the alumosilicates, is in great abundance. On the other hand, the second type is super-saturated with earthy alkali carbonates, consequently the SiO_4 part is greatly decreased. In Fig. 1, I illustrate this by diagrams, showing the equivalent-percents of the cations or anions in five Hungarian alkali soils. The Om or oxide rest-equivalent represents the lack of acid equivalents in respect to the cations.

The third principle of the grouping may be the state of the salinization, alkalization, desalinization, or solotization. As regards this principle we may consider the following groups:

I. *Saline soils.*—Soils which are more or less impregnated with water-soluble salts but in which no considerable alkalization has taken place. It is not easy to find where the alkalization starts. In my studies of the chemical characteristics of soil-leaching processes I have found that the relative amount of the exchangeable K+Na in the equivalent-percents of the total (S) runs about 6.4 to 11.2 in tshernozem soils. Kelley has published similar results and stated an average of 12 per cent for the K+Na equivalents (6). As among the soils analyzed by Kelley, three are slightly alkaline if we exclude the soils No. 430, 302 and 2767; for the remaining four soils the respective values will run from 6.4 to 8.7 per cent. I think, therefore, if we consider the starting point of alkalization as about the figure of 12 per cent and accept this as provisional, until more analytical figures are available for neutral soils with no signs of alkalization, then we do nothing arbitrary.

II. *Saline alkali soils.*—Are those saline soils in which the alkalization is evidenced by the accumulation of the exchangeable alkali cations. The starting limit may provisionally be the above mentioned limit of 12 per cent; a sum of the exchangeable K and Na equivalent-percents, which may even reach 100 per cent, as evidenced by some American salinized alkali soil investigations by Kelley (5). In this main group the degree of salinization, that is the amount and quality of the water-soluble salts, is the determining factor.

III. *Alkali soils in desalinization of alkalinized saline soils.*—Departing from the above mentioned limit of about 12 per cent of the exchangeable alkalization-equivalents in the total of 100, we have the starting point of the desalinization, or the upper limit of alkalinized saline soils. It is hardly possible to desalinize an alkali soil without changes in the absorb-

ing-complex. If the soil has enough $CaCO_3$ or $CaSO_4$, these calcium salts may protect the absorbing-complex against solotization, and we get back a neutral soil like a tshernozem. But if these salts are absent or washed down into lower horizons, then the action of water and absorbed CO_2 will interact, displacing more or less of the exchangeable alkali cations, especially sodium cations, with hydrogen. As the presence of the sodium salts do prevent this reaction as far as the concentration of the sodium cations in solution might force back the hydrolysis of the sodium zeolites (humates); therefore, the solotization may begin, when the desalinization reaches that limit, by which the protective effect of the sodium salts ceases. This limiting factor may represent the practical limit of desalinization and the beginning of solotization. In the case of the "Szik" soil of Hortobágy (Hungary), we have found the following relation between the total salt content and the degree of unsaturation:

Horizon	*Total salt* *per cent*	*Degree of unsaturation* 100-V
A	0–0.1	44.1
B_1	0.1–0.2	14.7
B_2	0.3–0.4	10.6
B_3	0.4	11.0
C_1	0.25–0.30	10.8
C_2	0.20–0.25	10.8
C_3	0.20–0.25	14.2
D	0.20–0.25	14.2

It seems, that a degree of unsaturation of 15 is common for partly desalinized alkali soil and a total salt content of 0.1 to 0.2 per cent is likely to protect the absorbing complex about as far as this figure is limiting. Below 0.1 per cent of total salt it is likely that the solotization begins to increase the degree of unsaturation suddenly to 44.1. As I have no other data available along this line I would propose that we accept provisionally a salt content of 0.1 per cent as the lowest limit for this group combined with a rate of unsaturation (i.e.,100–V) around 15 per cent. It is to be noted that the determination was made by conductometrical titration, the theory of which I have developed elsewhere.

IV. *Alkali soils in degradation or solotization.*—These are soils with the alkali character but the exchangeable alkali cations are more or less replaced by hydrogen and the soils become unsaturated and slightly acid. This type of alkali soils is widely distributed in Hungary and according to Gedoriz, in Russia too (2). According to my knowledge we have no evidence that in America, or other arid zones, we have similar soils. It seems, however, very likely that such may be the case but as Gedroiz mentions, in Russia they previously treated similar soils as podsolized soils. "One can affirm—he claims—with a certain conviction, that very many degraded and podsolized soils, in more arid zones, than the dernovo pod-

sols, have originated by a similar process—that of degradation of the earlier alkaline soils, that were there" (2). It follows, that by artificial washing out of the salinized alkali lands, if they are free of $CaCO_3$ or $CaSO_4$ we may ultimately get artificially a degraded alkali soil or "soloti."

The next principle of grouping the salty soils might be their physical character. Starting with the mechanical composition and some characteristic physical properties: as permeability, porosity, strength, plasticity and shrinkage. Some of them are closely allied to each other and as regards the possibilities of practical reclamation it seems sufficient to group them in three mechanical classes as sandy, loamy and clay; subdivided in two or more subclasses as regards permeability. But at this very point, there is a great difference in permeability as long as the salt content of the soil is high enough to deflocculate the fine dispersion of alkalized soil, and when the soil is becoming desalinized artificially by irrigation. In the latter case, if the soil is poor in $CaCO_3$ or $CaSO_4$, the previously pervious alkali soil becomes more and more impervious.

Finally we might also consider the biological properties of the soil. I do not mean at present the microbiological flora of the salty soil, because on account of insufficient data we are hardly in a position to arrive at a classification. In the session of the third Commission my collaborators and I have reported upon some examples. But the macroflora of the salty soils is very instructive and of great practical value.

The recognition of soil character from the native vegetation was claimed by Hilgard in his book on "Soils" (3). The natural plant growth affords some means of indicating the quantity and quality of the salts in soils. "Alkali weeds"—as noted by Hilgard—"are commonly spoken of almost everywhere; but the meaning of this term—i.e. the kind of plant designated thereby—varies materially from place to place, according to climate as well as the quality of the soil."

The first studies in this line were started in California by Mr. Burtt Davy and Dr. R. H. Loughridge as far back as 1898 and 1899. Similar observations and studies were carried on since that in other countries, but, as Hilgard says, the natural vegetation varies from place to place. Therefore, each country or alkali type must be surveyed to determine the main plants, which may rightly indicate the salt content and in some way the quality of the harmful salts in soils. This was surveyed last summer in Hungary by Hungarian botanists and their results will be reported elsewhere.

The other side of this biological classification makes it necessary to know the resistance of useful plants for agriculture or grassing. Loughridge, of California, collected from his own observations (13) a great variety of various culture plants. But it is difficult to obtain a practical scheme for classification. That might have been the reason, that the salt classes in different areas of America varied according to mathematical

rather than to biological basis. I may cite only some examples for total salt content maps:

Class	*Roosevelt area* *Total salt* *per cent*	*Carlsbad area* *Total salt* *per cent*	*Salt-Lake Valley* *Total salt* *per cent*
1	0–0.25	0.0–0.25	0–0.25
2	0.25–0.50	0.25–0.50	0.25–0.40
3	over 0.50	over 0.50	0.40–0.60
4			0.60–1.00
5			1.00–3.00
			over 3.00

These salt classes were published before 1903, when I published my paper "Experiences on the Relation of Plants and Salt Content of the Alkali Soils in Hungary" (12). The aim of these studies was to arrive at a practical classification based upon the salt content and its quality for irrigated grass land. Then it was enlarged to include cultivated plants without irrigation and finally we get a practical salt classification not very different from the above mentioned American ones, but Class 1, of the latter, proved too large and the classes over 0.50 total salt, or 0.20 per cent $NaCO_3$, mean practically the same. The classification as regards the total salts was fixed as follows:

Class	*Total salt* *per cent*
I	0–0.10
II	0.10–0.25
III	0.25–0.50
IV	over 0.50

As regards the Na_2CO_3 content

Class	*per cent* Na_2CO_3
I	0–0.55
II	0.05–0.10
III	0.10–0.20
IV	over 0.20

It was necessary to combine these classifications as follows: In the combined classification the numerator represents the class by total salt content; the denominator, the class by Na_2CO_3 content.

Combined Classes

I Class $\frac{\mathrm{I}}{\mathrm{I}}$

II Class

Subclass II A $\frac{\mathrm{II}}{\mathrm{I}}$ or $\frac{\mathrm{I}}{\mathrm{II}}$

Do II B $\frac{\mathrm{II}}{\mathrm{II}}$ or $\frac{\mathrm{III}}{\mathrm{I}}$

III Class

Subclass III A $\frac{\mathrm{III}}{\mathrm{II}}$ or $\frac{\mathrm{II}}{\mathrm{III}}$

Do III B $\frac{\mathrm{III}}{\mathrm{III}}$ or $\frac{\mathrm{IV}}{\mathrm{II}}$

IV Class

Subclass IV A $\frac{\mathrm{IV}}{\mathrm{III}}$ or $\frac{\mathrm{III}}{\mathrm{IV}}$

Do IV B $\frac{\mathrm{IV}}{\mathrm{IV}}$

I will try to give here the general principles of the practical value of this combined classification:

I Class.—Alkali soil is not harmful for any cultivated plant, as cereals; wheat, barley, oats, rye, maize and other more sensitive dry farming plants. In irrigated lands the first class grasses *Alopeucrus Pratensis L.*, *Poa augustifolia*, then among the *Papilionaceae* the European lucerne, *Trifolium patense.* As in this class the salts are not harmful to most cultivated plants we will call this class of alkali soils, "productive" alkali.

TABLE 3.—Schematic presentation of soil classification

Salty Soils

I. Climatic principle:

Humid		Arid	
Brischore or Tundra Zone	Dendrochore or Podsol Zone	Poechore or Step Zone (semi-arid)	Desert zone (varied zone)

II. General chemical character of the soils:

A. Soils in which the alumo-silicates are ruling.

B. Soils in which the alkali-earth carbonates take over hand.

III. State of development of the formation of salty soils:

A. Saline Soils: Salt content and quality different but no appreciable alkalization (not more than 12 per cent K+Na equivalents in the total exchangeable kations (*S*)).

B. Saline Alkali Soils: More or less developed alkalization (over 12 per cent K+Na etc.) and different salt content.

C. Alkali Soils in Desalinization: In the equivalent per cents of the total exchangeable kations K+Na over 12 per cent. Rate of unsaturation not over 15 per cent. Salt content lowest limit—0.10 per cent total salt.

D. Alkali Soils in Degradation: Rate of unsaturation over 15 per cent. Salt content under 0.10 per cent.

IV. General physical character and structure of the soils:

Mechanical composition:	A. Sandy Soils	Pervious
	B. Loamy Soils	or
	C. Clay Soils	Impervious

Structure: or without Solonetz or Solontchak.

V. Biological properties based upon the salt content and quality and their relation to native and culture plants:

An example may serve the above given combined classification and considerations.

II Class.—Alkali soil without soil leaching, hardly cultivable, but the Subclass II A can easily change into Class I by natural drainage if the precipitation favors it, or by irrigation. The Subclass II B is much more resistant, and unless irrigated, hardly reclaimable. With irrigation this can be done depending upon circumstances, very rapidly.

III Class.—Alkali soil of this class is as a rule very resistant to reclamation especially the Subclass III B when the soil is heavy and impervious, hence natural or artificial drainage is unsuccessful. In these cases, however, by surface irrigation, we might get fairly good pasture, and the best

TABLE 4.—Illustrating the Application of Principle Proposed in Table 3

Grouping and Classification of the Hungarian Alkali Soils the so-called "Szik" or "Szék" lands

I. Climate: semiarid or step-zone.

II. Chemical character: dominant in the chemical composition are:

A. Alumino-silicates

III. Development:

1. Alkali Soils in Desalinization
2. Alkali Soils in Degradation

IV. Physical character and structure: Heavy clay impervious columnae or prismatical structure (Solonetz)

B. Alkali-earth Carbonates

1. Saline Alkali Soils
2. Alkali Soils in Desalinization

Clay — Permeable Impervious

Loam — Permeable Impervious

Sand — Impervious Calcareous Hardpan

Without Structure (Solontchak)

With Structure (Solonetz)

V. Biological Classification according to the combined salt classes:

	Total salt per cent	Na_2CO_3 per cent	
I. Class $\frac{I}{I}$	0–0.10	0–0.05	First class vegetation if irrigated or by dry reclamation with $CaCO_3$ or $CaSO_4$ excellent wheat fields.
II. Class $\frac{II}{I}$	0.10–0.25	0–0.05	Second class vegetation, with irrigation quickly reclaimed, dry reclamation uncertain.
A. or $\frac{I}{II}$	0–0.10	0.05–0.10	
B. $\frac{II}{II}$	0.10–0.25	0.05–0.10	Second class vegetation, reclamation with irrigation takes longer time, dry reclamation impossible or unproductive.
or $\frac{III}{I}$	0.25–0.50	0.0–0.05	
III. Class $\frac{III}{II}$	0.25–0.50	0.05–0.10	Third class vegetation, reclamation with irrigation possible but takes longer time.
A. or $\frac{II}{III}$	0.10–0.25	0.10–0.20	
B. or $\frac{III}{III}$	0.25–0.50	0.10–0.20	Third class vegetation, reclamation with irrigation unproductive, pasturing or fishery indicated.
$\frac{IV}{II}$	over 0.50	0.05–0.10	
IV. Class $\frac{IV}{III}$	over 0.50	0.10–0.20	Only fishery is indicated as long as the salts are partly removed.
A. or $\frac{III}{IV}$	0.25–0.50	over 0.20	
B. $\frac{IV}{IV}$	over 0.50	over 0.20	

way to make use of it in Hungary is to make artificial ponds for fisheries. The Subclass III A is easier to wash out and irrigation may be profitable.

IV Class.—Alkali soils, which are practically unproductive and with our heavy clay and impervious alkali lands leaching of the soil is impossible. But by establishing fishery ponds after some years the salts are washed deeper and the cropping may succeed for one or two years, and then be followed by 2 to 3 years fishery and so on, we get a succession of good profit as our experience in Hungary has proved.

Now I am aware, that under other climatic and soil factors the utilization of these different salt classes may be different, but it seems to me a good general basis on which we can build up on the one hand, the utilization for agriculture or, on the other hand, this might be a good basis to classify the natural plant vegetation for the different areas. If we are familiar with the leading natural plants of some alkali district, then the alkali soil mapping is much easier than without that.

To obtain now a survey of the general principles stated above of grouping and soil classification I have tried to compile schematically the succession of the principles in Table 3.

I think in this general outline each country might be able to insert its own salty soils, and we will get an international understanding of the different salines or alkali soils. As an example, I may illustrate, in Table 4, the application of the above principles on the Hungarian alkali soils. It is evident, that for this classification the whole soil profile is determinant and not a single soil horizon or layer.

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SUBCOMMISSION V

FOREST SOILS

Resolution in Regard to the Organization of a Subcommission on Forest Soils

A large number of delegates to the First International Soil Congress assembled in Washington, D. C., have met together on June 17 and 20, 1927, to hear and discuss papers on forest soils. These delegates have organized informally a subcommission on forest soils. They have the honor to present to the Executive Committee of the Congress the following recommendations:

(1) The great awakening of interest in forestry which is now taking place in countries of large forest areas like the United States, Canada, South America, Russia, Finland, Sweden, and Norway, brings forcibly to the front many important problems of forest soils. Forest soil science is one of the most important scientific foundations of forest practice. Forest soils involve very different problems from farm crop soils in that they can be studied only under natural conditions.

(2) The next International Soil Congress, if conditions permit, is to be held in Russia. This is a country of vast forests and forest soils. Russian soil scientists have made notable contributions to soil science, and forest soils will inevitably form an important phase of the discussions.

(3) For these reasons the delegates to the First International Soil Congress interested in forest soils strongly recommend to the Executive Committee of the Congress that forest soils be recognized as an important branch of soil science and that the informal subcommission of this Congress on forest soils be made permanent.

Barrington Moore	J. Kittredge, Jr.
Gustav Krauss	Fr. Weis
Eduard Schuster	K. D. Glinka
D. Albert	S. Neustruev
Henrik Hesselman	L. Prassolov
Raphael Zon	F. J. Alway
Peter Treitz	M. Driacca

Committee on Forest Soils

MINUTES OF INFORMAL SUBCOMMISSION ON FOREST SOILS

Dr. R. Zon, Acting Secretary

Friday, June 17. Prof. Fr. Weis of Denmark in the chair.

Meeting opened at 10 A.M. First paper presented was by F. J. Alway and C. A. Rost on "Effect of Burning the Forest Floor Upon the Produc-

tivity of Jack Pine Land." The paper was discussed by Barrington Moore, Shaw, and Hesselman.

The second paper was by S. A. Waksman, on "Aerobic and Anaerobic Decomposition of Oak Leaves." From 10:25 to 10:47 A.M. A number of questions were asked but discussion was discontinued.

The third paper was by Dr. E. Melin, on "The Mychorriza Fungi of Trees and Their Rôle in Nutrition." Considerable discussion by Fred Hesselman and Dr. Melin. Time consumed from 10:47 to 11:15 A.M.

The fourth paper of the morning was by Joseph Kittredge, "The Use of Soil Surveys in Forest Classification." Discussion by Shaw, Zon, and Barrington Moore. From 11:15 to 11:37 A. M.

The fifth paper was by Dr. G. Krauss. Dr. Krauss gave the gist of two papers, one on "Graphic Representation of the Results of Numerous Mechanical Soil Analyses" and the other on "Variations in the Calcium Content of Copper Beech on Various Sites." The presentation of the paper and its discussion lasted until 12 o'clock.

As only a part of the papers assembled for this discussion could be presented in the forenoon, the meeting unanimously decided to continue the hearing and discussion of the rest of the papers Monday forenoon, June 20.

MONDAY, JUNE 20. Prof. Fr. Weis of Denmark in the chair.

The meeting got under way at 9:52 in Room 410. The first paper was by Henrik Hesselman on "Forest Humus." This was illustrated by lantern slides. Prof. Hesselman spoke in English and presented a clear picture of the formation of nitrates in different kinds of humus. Time consumed, 9:52 to 10:25. There was no discussion.

The second paper was by Prof. P. Albert. He covered two subjects, one "The Mechanical Composition of Dune Sands and Its Significance for the Productivity of These Soils in Forests," and the other "Application of the Improved Apparatus for Measuring the Resistance of Soils to the Determination of the Structure of Forest Soils." He demonstrated an instrument for measuring the resistance or compactness of the soil. Time, 10:25 to 10:40 A.M.

The third paper was by Fr. Weis of Copenhagen. He presented the results of his investigations on "Investigations on Danish Heath Soils." Both Albert's and Weis's papers were briefly discussed and a number of questions were asked particularly as to the use of the new instrument. Prof. Albert distributed a description of the instrument with the address of the manufacturers.

Prof. Morgan of New Haven remarked that his investigations in Connecticut fully confirm the results of the Danish investigation. Time of Prof. Weis's paper, 10:40 to 11:20 A. M.

The fourth paper was by Raphael Zon on "Silviculture as a Factor in

Retaining the Fertility of Forest Soils." Time, 11:20 to 11:45 A.M. The paper brought out the question of closer cooperation between soil scientists and foresters and the means of bringing it about. As a result of the discussion in which Weis, Moore, Hesselman, Kittredge, and Alway participated, the chairman appointed a committee to draft a resolution on the desirability of organizing a permanent subcommission on forest soils at the Second International Congress on Soil Science. A copy of the resolution and the members of the committee is attached.

The last paper of the morning was by Prof. F. J. Alway of Minnesota, on "Effect of Burning the Forest Floor Upon the Productivity of Jack Pine Land." This paper took only 10 minutes, and gave the results of experiments on five plots, some of which were completely burned over, others moderately burned, and still others undisturbed.

The meeting adjourned at 12 o'clock, with still a fairly large number of papers not presented. These it is hoped may be printed in the proceedings of the Soil Congress.

The Committee on Forest Soils appointed by the Chairman met at luncheon at the Cosmos Club and drafted the resolution which has already been referred to.

Discussion of Dr. Albert's paper, "Die mechnaische Zusammensetzung der Dünensande (nach Atterberg) under ihre ausschlaggebende Bedeutung fur deren Wuchsleistungen als Waldboden," by Dr. N. G. Hörner.

Some Swedish inland dunes seem to miss such a clear relation between the mechanical composition of the sand and the vegetation as Professor Albert has found in Germany. The main part of the Swedish eolian sand is found between the limits 0.6 and 0.06 mm. grain size. Quite often the fractions on both sides of the critical point 0.2 mm. are represented by almost the same percentage, but sometimes there are large variations. Mechanical analysis of sand from inland dunes in Värmland, Sweden, show an amount below 0.2 mm. grain size from 17 per cent to 84 per cent. The variations in the vegetation does not seem to correspond with these changes in the mechanical composition of the sand.

It may not be of great importance in this special case, but as a rule the stratification of a soil should be considered in the discussion of soil and moisture. Even dunes show great differences in structure. If the sand contains only a small amount of fine fractions, its retarding effect on sinking water may be greater if the fine material is concentrated to thin, and wide, flat strata than if it is scattered among the coarser grains. In stratified dunes, as in many other deposits, the different inclination of the strata makes the question more complicated.

COMMISSION VI

THE APPLICATION OF SOIL SCIENCE TO LAND CULTIVATION

President

ING. J. GIRSBERGER, Zurich, Switzerland

Vice Presidents

ENG. E. GIOVANNONI, Rome, Italy
OBERBAURAT O. FAUSSER, Stuttgart, Germany
DR. J. ZAVADIL, Brno, Czechoslovakia
MR. S. H. MCCRORY, Washington, D. C.

Secretary

DR. R. JANOTA, Prague, Czechoslovakia

Members

DR. ENG. P. ZUNKER, Breslau
DR. C. SKATNICKI, Warsaw

Dr. J. Girsberger, President of Commission VI, reported the Washington Sessions of the Congress as follows:

KONKLUSIONEN

DER 6. KOMMISSION DER "INTERNATIONALEN BODENKUNDLICHEN GESELLSCHAFT" ANLÄSSLICH DES I. INT. BODENKUNDLICHEN CONGRESS 13.–23. JUNI, 1927, IN WASHINGTON

1. BEWÄSSERUNG

Aus den gehaltenen Vorträgen über "Bewässerung" geht hervor, dass für diese verschiedene Methoden anwendbar sind. Zur Zeit fehlt aber noch die Abklärung über die jeweilige zweckmässigste Methode für die verschiedenen Böden und übrigen Verhältnisse, insbesonders auch in bezug auf die chemische und physikalische Beschaffenheit der Böden. Speziell muss näher untersucht werden, wie die Bewässerung am zweckmässigsten durchgeführt werden soll, ob durch Anlage offener Gräben, oder durch Beregnung, oder durch unterirdische Wasserzuführung.

Dabei ist jeweils zu prüfen, ob nicht durch besondere chemische oder physikalische Eigenschaften des Bodens die Wirkung der Bewässerung irgendwie beeinflusst wird.

2. ENTWÄSSERUNG

Es wird festgestellt, dass die Draintiefe sich zwischen 1.0 und 1.5 m. bewegt, besondere Fälle nach beiden Richtungen him ausgenommen.

Eine normale Draintiefe gibt es nicht; diese is vielmehr von den ortlichen Verhältnissen abhängig.

Zur Bestimmung der Drainentfernung wird die Durchführung der mechanischen Schlämmanalyse und Grundwasserstands-Untersuchungen erforderlich. Die mechanische Bodenanalyse wird in der Kulturtechnischen Praxis am besten nach der Spülmethode von Kopecky durchgeführt, unter Beibehaltung der von ihm vorgeschlagenen 4 Korngrössengruppen.

Fur die Prüfung der zweckmässigsten Anlage von Drainagen und ihrer Wirksamkeit wird gemäss den Vorschlägen von Fauser den Regierungen die Einrichtung von Versuchsanlagen empfohlen. Über die erhaltenen Ergebnisse soll der 6. internat. Kommission der I. B. G. womöglich jährlich Bericht erstattet werden.

Den technischen Stellen, welche sich mit Entwässerungen zu befassen haben, wird ferner empfohlen, im Sinne der Ausführungen von Bijl Erhebungen uber die Ertrags- und Wertsteigerungen entwässerter Böden zu machen und sie ebenfalls der vorgenannten Kommission zur Verarbeitung zu zustellen.

3. Erosion

Die Verhinderung und Regulierung der Erosion ist von grösster Wichtigkeit für viele Länder. Die Anlagen für die Bekämpfung und Regulierung der Erosion sind aber bisher um nach empirischen Regeln ausgeführt worden. Es ist wünchenswert, dass Untersuchungen veranstaltet werden zur Feststellung der Regeln für die Anlage von Verbauungen zur Bekämpfung oder Verhütung der Erosion.

4. Moorkultur

Die grosse Entwicklung der Moorforschung in wissenschaftlicher und praktischer Hinsicht lässt es als angezeigt erscheinen, dass in allen Ländern genaue Untersuchungen über die Natur der Moore, ihre Kultivierung und Verwertung angestellt werden.

Insbesonders soll der Versuch gemacht werden, auf den nächsten Kongress hin für die Nomenklatur und die Methoden, die für praktische und wissenschaftliche Untersuchungen nötig sind, Einheitlichkeit zu schaffen.

5. Die Bestellung des Vorstandes der 6. Kommission

Es werden folgende Vorschläge gemacht:

Präsident: Kultur-Oberinger. J. Girsberger, Zürich, Schweiz
Vizepräsidenten: Ingr. E. Giovannoni, Rom, Italien
Oberbaurat O. Fauser, Stuttgart, Deutschland
Mr. McCrory, Washington, D. C., U. S. A.
Prof. Dr. J. Zavadil, Brünn, Tschechoslowakei
Prof. N. M. Tulajkow, Saradow, Russland

Sekretär:	Dr. Ing. R. Janota, Prag, Tschechoslowakei
Mitglieder:	Prof. Dr. Ing. P. Zunker, Breslau, Deutschland
	Prof. Dr. C. Skatnicki, Warschau, Polen

6. BILDUNG EINER SUBKOMMISSION FUR MOORKULTUR

Die 6. Kommission schlägt vor, eine Subkommission für Moorkultur zu bilden und deren Leitung Herrn Prof. Dachnowski zu übertragen. Die Kommission soll im übrigen selbst constituieren.

Washington, D. C., den 22. Juni, 1927.

Für die Richtigkeit dieser Protokollierung:

(Sign.) J. GIRSBERGER, Präsident
S. H. MCCRORY
ALFRED P. DACHNOWSKI
H. SCHILDKNECHT

Dr. A. P. Dachnowski-Stokes, reported the organization of Subcommission I for the study of Peatlands. This organization was effected at the second session of Commission VI.

REPORT OF THE ORGANIZATION OF SUBCOMMISSION I FOR THE STUDY OF PEATLANDS

DR. A. P. DACHNOWSKI-STOKES

At the second session of Commission VI of the First International Congress of Soil Science held at Washington, D. C., on June 15, 1927, the acting chairman Mr. S. H. McCrory, communicated to the members a proposal submitted to the President of Commission VI, Mr. J. Girsberger, with regard to the formation of a Subcommission for the study of peatlands. This proposal was defined in a letter from Dr. A. P. Dachnowski which was addressed officially to the Executive Committee of the Congress but was left with Commission VI for further action. Following is the text of the letter:

"Owing to the rapidly growing content of information from peat specialists and Peat Institutes, as well as the increase in number of publications and workers in this specific field, it is deemed desirable to provide for cooperative effort which would also have the effect of rendering the relation between peatlands and the means for their investigation and improvement the subject of a special and permanent international organization.

"In compliance with paragraph 10 of the Statutes of the International Society of Soil Science, I have been authorized to petition the General Committee of the Congress to approve the formation within this Society of an organization either as a Section of the Sixth Commission or preferably as Commission VII for the study of peatlands (Moorkunde)."

After a preliminary discussion the motion was made and approved unanimously to form within Commission VI a Subcommission for the study of peatlands. With a view to obviating delay and achieving satisfactory results as soon as possible the following were appointed to administer the work of the subcommission:

Chairman: A. P. Dachnowski-Stokes
Secretary: Hugo Oswald
Committee: B. Tacke, J. Girsberger, L. von Post, S. H. McCrory, F. J. Alway, W. S. Dokturowski, A. Kirsanov, F. E. Clements.

The general scope of the subcommission's activities may be indicated as follows: the subcommission proposes to maintain relations, on an international basis, with institutions interested in peatland problems, to encourage and assist in cooperative peat investigations or continuous group research, and to aid in coordinating data and experimental results obtained upon well identified peatlands in different countries.

It is further proposed that the subcommission consider the best means of coordinating and applying in a practical way the advances made in the several branches of peat investigations, and assure international cooperation in investigating the difficulties which stand in the way of the fullest development of peatland resources.

Proposals and recommendations may be initiated by members engaged in the various phases of peat investigations. An International Committee of the Subcommission, organized on a basis of divisional activities, is to offer suggestions and recommendations for consideration and approval, and aid in making up the program for the next session of the Soil Science Congress.

The above report, relative to the organization and activities of Subcommission I for the study of peatlands, was read and accepted by unanimous vote at the opening of the third session, meeting on June 17, 1927.

The following program was carried out at the first session of Subcommission I, meeting on June 18, 1927, in room 407 of the U. S. Chamber of Commerce in Washington, D. C.

8:30 to 9:30. Peat exhibit.

9:30 to 11:30. Reading and discussion of invited papers:

A. P. Dachnowski-Stokes, U. S. Dept. of Agriculture, International problems in the study and utilization of peatlands.

W. Wolff, Berlin, Germany, Peat investigations in Germany.

H. Oswald, Jönkoping, Sweden, Peat investigations in Sweden.

J. G. Byjl, Hoofdorp, Holland, Moorkultur und Wasserabfuhr.

D. J. Hissink, Groningen, Holland, Chemical composition of Dutch organic and peat soils as criterium for the classification of these soils.

B. F. Haanel, Ottawa, Canada, Peat investigations in Canada.

J. H. Beattie, U. S. Dept. of Agriculture, Prevention of wind damage to crops on peat soils.

F. J. Sievers, Pullman, Wash., Muck and peat lands of the Pacific Northwest.

P. M. Harmer, East Lansing, Mich., The production of special crops on Michigan Muck lands.

During this session the motion was offered and passed unanimously that a national or American Section be formed within Subcommission I and that a committee, selected by A. P. Dachnowski be impowered to appoint a chairman, vice chairmen, and a secretary to conduct the activities of the American Section.

It was further moved and unanimously accepted that the International Committee of the Subcommission be requested to prepare a draft relative to securing uniformity in international methodology and nomenclature required for research and technical procedures in peatland problems and report its recommendations to the next Soil Science Congress.

The session of Subcommission I for the study of peatlands adjourned at 11:30 A.M.

At the final session of the First Congress of the International Society of Soil Science, the following resolution was passed on June 22, 1927:

"*Peatland utilization:* The great advances in peat investigations from a scientific and practical standpoint make it advisable that in all countries detailed studies be carried out concerning the nature of peatlands, their cultural development and utilization.

"In particular the attempt should be made to secure for the next congress uniformity in nomenclature and methodology required for practical and scientific research in peatland problems.

"The Sixth Commission recommends that a Subcommission be formed for the study of peatlands (Moorforschung) and that its direction be entrusted to Dr. Alfred P. Dachnowski. The Subcommission is to make up its own organization."

Dr. D. J. Hissink, Acting President of the Congress, made a special report upon the chemical investigations of peat soils:

THE CHEMICAL INVESTIGATION OF PEAT SOILS

Dr. D. J. Hissink, Acting President

I had an opportunity to look through the "Bulletin VIII, Report of the Seventh Annual Meeting of the American Soil Survey Association," on page 64 of which is given the "Report of the Committee on Organic Soils."

This report comes, amongst others, to the following conclusion: "The soil (organic soils) should be classified on the basis of intrinsic characteristics; criteria such as ash content, color, texture, thickness, density, reaction, lime content, nature of substrata, etc., should be employed."

To these criteria, I would propose to add the following: Nitrogen and phosphoric acid content and especially the values:

K(humus) equals g. CaO per 100 g. humus;
N(humus) equals g. nitrogen per 100 g. humus;
P(humus) equals g. phosphoric acid per 100 g. humus.

Potential adsorption equals g. CaO which 100 g. soil must adsorb, for the humus to contain 5 per cent CaO (see Volume A, pp. 192–193). This value may also be calculated on 100 g. humus instead of on 100 g. soil.

A research of various organic Dutch soils, especially peat soils, has proved the great importance of these values as criteria for the classification of the organic soils.

There seems to be some relation between the K(humus)-value of the soil and the soil reaction (pH), the K(humus)-value being in very acid soils (pH about 4) about 1 to 1.5 and in more or less neutral soils about 5.

The N(humus)-value gives an idea of the humification of the organic matter and at the same time of the assimilability of the nitrogen. In badly humified new peat soils with a very acid reaction the N(humus)-value was about 1 as compared with about 4 to 5 in neutral or slightly alkaline, good, humified, peat soils.

PART II
COMMISSION I

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THE GROUPING OF FRACTIONS IN MECHANICAL ANALYSIS

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INTRODUCTION

One of the greatest difficulties in the way of securing comparisons between soils of different countries is the lack of uniformity in analytical methods. This is nowhere felt so acutely as in the mechanical analysis of soils. Among all the analytical determinations carried out on soils, mechanical analysis is probably the most important from the point of view of characterizing a soil. Yet in view of the great variety of methods hitherto employed in different countries it has not been possible for an English pedologist, for example, to compare his own soils with the soils of Russia, Germany, or any country where different methods of mechanical analysis are used. The need for international agreement has long been felt and in the meeting of the First Commission in Berlin in 1913, the matter was thoroughly discussed. Cooperative effort towards a unification of methods, interrupted by the war, was resumed at Praha in 1922 and as a result of plans made then, it was possible in Rome in 1924 to discuss the results of comparative analyses made by different methods of dispersion and to plan the scheme of cooperative work leading up to the meeting of the Commission at Rothamsted, England, in October 1926.

The question of the preliminary treatment of soil to secure adequate dispersion before mechanical analysis forms the subject of a separate discussion. My task is to discuss the problem of the grouping of fractions in mechanical analysis. The great variety of scales proposed for the classification of fractions in mechanical analysis is so well known that it is unnecessary to allude to them individually. In the proceedings preliminary to the meeting of the First Commission at Rothamsted, an effort was made to ascertain the views of workers as to the most suitable scale. There was general agreement as to the necessity for international agreement, but there were differences of opinion as to the most suitable scale for actual adoption. The well known Atterberg scale had, however, the largest number of adherents.

The difficulties in the way of an international agreement are rather more than the problem of diameter limits. There is first of all the important question as to the basis on which results should be expressed. Here there is a perplexing choice. For example, in our English method, the fractions are ignited and free from carbonate. The volatile matter (hygroscopic

moisture and ignition loss) and carbonates being expressed separately. In other methods, the only items which appear in the analysis are the actual fractions, which are dried at 100 to 105° and include carbonates and organic matter. Even where carbonates are removed before mechanical analysis and appear as a separate item, the actual fractions may either be given on the ignited basis or dry at 100 to 105°.

This difficulty was fully discussed at the Rothamsted meeting. It was recommended that two kinds of preliminary treatment should be recognised, namely (1) water treatment without chemical reagents, and (2) treatment with hydrogen peroxide and hydrochloric acid where ultimate dispersion is desired. In the former case, the analysis will simply show the fractions dry at 100 to 105° and including the carbonates and organic matter. In the latter case, the fractions will be expressed carbonate-free, humus-free, and dry at 100 to 105°. The carbonates will be shown separately as the result of a separate determination and the difference from 100 will be reported as humus, etc. A direct determination of the humus will also be necessary since the difference figure will be loaded with all the errors. It is perhaps necessary to discuss what is meant by humus in this connection. Treatment with hydrogen peroxide oxidizes or renders soluble the humified organic matter and does not attack the non-humified material. We have found in experiments at Bangor that about 80 per cent of the total organic carbon of ordinary soils is in this humified state. We use the term humus in this paper to refer to the peroxide-soluble organic matter. The fractions in the mechanical analysis as proposed will thus contain non-humified organic matter which has resisted the action of hydrogen peroxide. One advantage of the English method is that all fractions are ignited and thus any organic matter surviving peroxide treatment is removed.

Whether or no the Conference as a whole approves the recommendations of the Rothamsted meeting in respect to the basis on which the results should be expressed, *it is extremely desirable that in all published results, the exact basis on which they are expressed should be clearly stated.*

GROUPING OF FRACTIONS IN MECHANICAL ANALYSIS

We now return to the major problem of the actual grouping of the fractions. The existing confusion consists not merely in the different scales in use but in the meaning to be attached to them. Thus the clay fraction is defined as less than 0.002 mm. both in the English and in the Atterberg scale. But actually these are not equivalent, because the limiting velocity in the English scale is laid down as 0.0001 cm. sec. (24 hr. 8.64 cm.) and in the Atterberg scale as 0.000347 cm. sec. (8 hr. 10 cm.). It cannot be too strongly emphasised that except where, as in the case of the mechanical analyses made by the United States Bureau of Soils, an attempt is made to control particle size by measurement, the particle size

limits generally used have only a secondary significance. The actual basis of separation is the settling velocity or, in the case of elutriation methods, the hydraulic value. In the opinion of the writer, the most satisfactory solution of this difficulty would be to define all fractions by means of their settling velocities. But since there is a general desire that diameter limits should still be used for the *description* of fractions, the same end would be served by setting up an agreed scale of correspondence between particle sizes and settling velocities. This recommendation appears among the findings of the Rothamsted meeting and the following scale was proposed for a settling depth of 10 cm. at 20° C.:

Time of sedimentation through 10 cm.	Diameter of particles Upper limit
5 sec.	0.2 mm.
7.5 min.	0.02 mm.
8 hr.	0.002 mm.

Intermediate values are to be obtained by interpolation. The specification of the temperature is important. Owing to the great changes in the viscosity of water with temperature, serious divergences may occur if no account is taken of this variable.

It must, of course, be understood that the acceptance of such a scale does not imply that by using a settling time of 8 hours and a depth of 10 cm. an exact separation is effected between particles respectively greater and less than 0.002 mm. diameter. The exact limiting diameter corresponding with any settling velocity will depend on the nature of the mineral particles present. With micaceous particles the diameter corresponding with this settling velocity would be greater than 0.002 mm., with heavy minerals less than 0.002 mm. *What the table does mean is that when a fraction is described as being less than 0.002 mm. it has been separated by using a velocity corresponding with 10 cm. and 8 hr. at 20°* C.

It will be noticed that, in the recommendation of the Rothamsted meeting, it is stated that other particle size-velocity relationships shall be obtained by interpolation. An inspection of the scale will show that the relationships recommended do not accord with Stokes' Law. During the discussion the view was expressed by some members that it would be more satisfactory to proceed from a single relationship, e.g. 10 cm. 8 hr. = 0.002 mm.; and to obtain all the other relationships by assuming the validity of Stokes' Law. Further consideration of this point has convinced the writer that this would be a simpler and safer course and the following scale is tentatively suggested.

For higher particle sizes than 0.02 mm. sedimentation methods become increasingly subject to error and it is doubtful if an accurate separation could be effected using any settling time of less than 5 minutes. Elutriation methods may, however, be permissible provided that correspondence

between settling velocity and hydraulic value holds good. A further task of the Commission should be to determine this point, or if there is not an exact correspondence, to determine the hydraulic value equivalent to each settling velocity. It is probably more satisfactory to separate the coarser fractions by means of appropriate sieves. For the purpose of constructing mechanical analysis curves it is, however, desirable to assign settling velocities to the coarser fractions, even although they are separated by sieving. It is, of course, possible that the sedimentation principle might be preserved throughout by the use of liquids of higher viscosity in the separation of the coarser fractions.

TABLE 1.—Scale to determine particle size-velocity relationships by interpolation
(For a settling depth of 10 cm.)

Time		Settling velocity		Upper limit of particle size
Atterberg scale	Suggested scale	Atterberg scale	Suggested scale	
8 hr.	8 hr.	0.00347 cm. sec.	0.00347 cm. sec.	0.002 mm.
7.5 min.	4 min. 48 sec.	0.0222 cm. sec.	0.0347 cm. sec.	0.02 mm.
5 sec.	2.88 sec.	2.0 cm. sec.	3.47 cm. sec.	0.2 mm.

The settling velocity for any particle size can be readily calculated if one relationship is assumed and Stokes' Law be used for the other particle sizes. A convenient method of dealing with this matter is by the use of nomograms as suggested by Dr. E. M. Crowther.

The great difficulty in the way of setting up an international scale is that already in different countries large numbers of analyses have been carried out by different methods. It is rather difficult to expect workers who have accumulated thousands of analyses, using a particular scale, to abandon it in favour of a new scale for which they will have to acquire new standards of judgment. In the view of the writer the methods which have already been in long use are certain to persist side by side with any international scheme which may be devised.

It must be recognised that there are two distinct purposes in mechanical analysis. Firstly there is the use of mechanical analysis for practical purposes as a basis for recommendations as to drainage, cultivation, etc. There is no reason why the same method should not be used for both purposes but since very large numbers of mechanical analyses have been made with the second end in view and certain standards of judgment have been arrived at, it is unlikely that methods so long in use will be abandoned. The writer would therefore suggest that in all scientific publications which may be expected to have an international circulation mechanical analysis should be given according to an agreed international system,

which shall exist side by side with other systems already in long use. In countries where mechanical analyses have not been accumulated in large numbers, the international scheme should be adopted for all purposes. It is, however, advisable to arrange that results obtained by other scales may be translatable into the terms of the international scale if necessary.

At the Rothamsted meeting, definite recommendations were made as to the methods of dispersion in mechanical analysis and as to the basis on which results should be expressed. So far as the particle size groups are concerned, the Commission has not gone further than suggesting a scale of correspondence between particle size and settling velocity. The writer pointed out at the Rothamsted meeting that by the use of mechanical composition curves[1] it is easily possible to transfer results from one scale to another. It is only necessary to set out the results with the summation percentages (e.g. Fraction I, Fraction I+II, Fraction I+II+III, etc.) as ordinates and the logarithms of the corresponding settling velocities as abscissae and from the curves obtained the summation percentages corresponding with any other settling velocities can be obtained by interpolation and extrapolation. The examples given at Rothamsted will illustrate this point for a certain soil (London Clay).

TABLE 2.—Example of settling velocities obtained by interpolation and extrapolation

Fraction	Atterberg scale		English scale	
	Calculated from analyses made on English scale	Experimentally found	Calculated from Atterberg scale	Experimentally found
I	44.0	45.0	38.3	37.3
II	22.5	20.8	23.5	24.7
III	21.0	21.2	11.5	12.7
IV	0.0	0.0	13.7	12.6
$CaCO_3$	0.0	0.0	0.0	0.0
Humus, etc.	12.5	13.0	13.0	12.7

It is thus possible to translate results from any scale to any other scale if the settling velocities are known. The only condition is that the basis of expression shall be the same. It, of course, is not possible by calculation to translate analyses in which the fractions include calcium carbonate and humus to analyses where these constituents are expressed separately. For international publications it would be preferable that all results should be actually obtained by the agreed international method, and it might be desirable to insist that any mechanical analyses given in articles intended for the Proceedings should be made by the international method.

[1] Actes de la Quatrième Conference Rome 1924, Vol. II, 180.

DECISIONS TO BE MADE BY THE COMMISSION

The task of the Commission appears to the writer to be to decide on the following points:

(1) What relationships shall be prescribed between settling velocities and particle size? The Atterberg scale gives a basis for such a series of relationships, but since the different values are not in accord with Stokes' Law, it might be better to proceed from a definite relationship, either 8 hr. 10 cm. = 0.002 mm. or 7.5 min. 10 cm. = 0. 02 mm. and obtain all the other relationships by assuming Stokes' Law. The latter course would probably be the simpler.

(2) Agreed that an international scheme for mechanical analysis is desirable, what scale shall be adopted for the different fractions? If it is desired to retain the Atterberg scale, then any results obtained with other scales can be transferred by graphical methods using the velocities of the Atterberg scale. If it is agreed that the velocities shall be brought into line with Stokes' Law, then these must be used instead of those at present prescribed for the Atterberg scale. Since any international scale is likely to be used in addition to existing scales, it might be simpler to define the fractions simply by means of settling velocities and to arrange that the successive fractions shall be defined by velocities which are simple fractions of unity, e.g. 0.0001, 0.001, 0.01, 0.1 cm. sec. This would greatly facilitate the logarithmic expression of velocities where it is desired to use mechanical composition curves.

Possible schemes for an international scale are summarised in Table 3 as follows:

TABLE 3.—Schemes for an international scale

Fraction	Atterberg scale [a]		Modified Atterberg scale [b]		Settling velocity scale	
	Settling velocity	Particle size	Settling velocity	Particle size	Settling velocity	Particle size
	cm. sec.	mm.	cm. sec.	mm.	cm. sec.	mm.
I	0.000347	less than 0.002	0.000347	less than 0.002	0.0001	Calculated if necessary starting from 0.002= 0.000347 cm. sec. and assuming Stokes' Law
II	0.0222	0.002–0.02	0.0347	0.002–0.02	0.001	
III	2.0	0.02–0.2	3.47	0.02–0.2	0.01	
IV					0.1	

[a] Other relationships to be obtained graphically by interpolation.
[b] Other relationships to be calculated by Stokes' Law.

On the whole, the writer would prefer the last scale, since mechanical analyses are actually based on settling velocities and the particle sizes are simply descriptions of the fractions, except in the case of the coarsest fractions where particle sizes are actually controlled by the use of sieves.

(3) What shall be the specified temperature? If 20° C. is adopted, then in analyses conducted at other temperatures the settling velocities must be corrected for viscosity. The velocities to be used at different temperatures, putting the velocity at 20° C. = 1.000 would be, 0.767 at 10°, 0.880 at 15°, 1.000 at 20°, 1.125 at 25°, 1.257 at 30° C.

DISPERSION OF SOILS FOR MECHANICAL ANALYSIS

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INTRODUCTION

In making a mechanical analysis of a soil, the primary object is to obtain some idea of the proportions of the different sized grains that make up the soil material. In making the separations, water is practically always used as the dispersion medium whether the method adopted is one of sedimentation or elutriation. There are two points of view as to the degree of dispersion desired in making such analyses. From one it is desirable to carry the dispersion as far as possible to separate the sand or mineral grains, to break down any soil aggregates, to entirely remove any colloidal covering from the grains, so that the final result furnishes a picture of the quantities of the various sized constituents that make up the soil mass. This generally involves mechanical and chemical treatment. From the other point of view it is desirable to secure such dispersion as would come about only by the mechanical shaking with water, to preserve many soil aggregates and probably not to remove much of the colloidal coating on the mineral grains. The final result here furnishes a picture of the soil constitutions on the basis that aggregates not broken down by such treatment, or colloid still adhering to the mineral grains will be likely to continue to exist in these forms in the soil under natural conditions or ordinary tillage operations. It is contended that such an analysis, from a practical viewpoint, furnishes information of most value as to the texture of the soil in the field, and gives some indication of its structure.

There is much to recommend each kind of treatment and also some criticism of each. For laboratory comparisons of the mechanical constitution of soils, a method producing complete dispersion is desired; perhaps for a knowledge of the field condition, a less exact separation is sufficient. We have encountered in the field soil material showing characteristics of a sandy loam, very friable even when recently wet, and decidedly granular, but on analyzing, using a complete dispersion method, was found to be classed from the analysis as a clay soil. In spite, however, of the obvious desirability of obtaining through analysis an indication of the field characteristics of a soil as to presence of aggregates, a mechanical analysis for this purpose has one serious disadvantage. In any treatment with water there is necessarily some dispersion of the aggregates present, and some loosening of the colloids from mineral grains.

The grains and aggregates do not separate exactly into the same units that exist in the soil. Since some dispersion is inevitable, but the exact amount is indeterminable under mere mechanical treatment, for purposes of comparison, a method of dispersion that will separate the material into the ultimate particles is desirable. Since many duplicate analyses with non-concordant results convinced us that the difficulty lay in the matter of unequal dispersion or differences in disintegration of aggregates, a study was undertaken of some of the methods of dispersion. This has resulted in the conclusion that chemical treatment is necessary to produce complete dispersion.

OUTLINE OF INVESTIGATION

Routine mechanical analyses have been performed in this laboratory for a number of years according to the method outlined by Fletcher and Bryan (2). In this investigation, their method was followed in separating the fractions, the only change being made in the preparation and treatment of the samples prior to the separation. In all cases 5 g. of air-dry soil material was taken as a sample, the moisture content being determined separately, and the results calculated to the oven dry basis. For purposes of comparison the sand group was not separated, the soil material being divided into three classes, sand 2.0 to 0.05 mm., silt 0.05 to 0.005 mm., and clay less than 0.005 mm. The colloid determinations were made according to the method of Robinson (5) using the factor 0.298 for the adsorption of the colloid.

The primary object of this investigation was to find a method of mechanical analysis suitable for rapid routine determinations which would indicate as nearly as possible the ultimate mechanical composition of the soil material. Although the percentage of clay alone may be objected to as a measure of dispersion, a consideration of the percentages of sand and silt together with the clay may be used as a fair indication of the degree of dispersion obtained.

EXPERIMENTAL METHODS

A brief outline of the methods of dispersion used in this investigation follows:

Method A. According to Fletcher and Bryan (3). The sample is placed in an 8 ounce nursing bottle with 100 cc. of water and 1 cc. of concentrated NH_4OH and shaken 7 hours.

Method B. Rubbing and decantation. The sample is placed in a porcelain or glass mortar with a very little water and rubbed with a rubber pestle. More water is added, the sand allowed to settle out, the silt and clay decanted together, and the operation repeated until no more silt and clay are removed. The silt and clay are then separated by means of the centrifuge.

Method C. According to Joseph and Martin (4), 100 cc. of a 0.2 per cent solution of Na_2CO_3 is added to the sample and shaken 2 hours.

Method D. The sample is boiled in water 1 hour, cooled, 5 cc. of N NaOH added and made up to 100 cc. and shaken 2 hours.

Method E. The sample was boiled 1 hour in 100 cc. of 0.1 N HCl washed [1] free of acid and shaken 7 hours in 100 cc. of 0.05 N NaOH.

Method F. The same as Method E except that the boiling was omitted.

Method G. The sample was boiled in 100 cc. of water for 1 hour 10 cc. of N HCl added and just brought to the boiling point, allowed to stand over night, washed and shaken 2 hours in 100 cc. of 0.05 N NaOH.

Method H. Same as Method G except that after the acid was removed the sample was dispersed in 5 cc. of concentrated NH_4OH in 100 cc. of water and shaken 2 hours.

The results of these various treatments on a sample of Stockton clay adobe are shown in Table 1.

TABLE 1.—Mechanical analysis of the Stockton clay adobe

Method	Sand	Silt	Clay
	per cent	per cent	per cent
A	30.1	31.6	38.3
B	17.3	32.9	49.8
C	21.0	25.0	54.0
D	20.0	24.9	55.1
E	19.9	22.6	57.5
F	19.8	23.3	56.9
G	19.2	22.9	57.9
H	19.8	23.4	56.8

This sample was selected for this work because analyses by the regular method (Method A) evidently did not show the true quantity of clay in the soil material. The results in Table 1 indicate that this conclusion was correct. It is interesting to note that Methods C to H give practically the same results in each case. The results by Method B, although indicating more clay than by Method A, show less sand than any other method. This is due to the fact that in order to get much effect from the

[1] The sample was washed free of acid in this and the following methods as follows: at the end of the acid treatment the sample was allowed to settle and the supernatant liquid poured off into a centrifuge tube. Fresh water was added to the sample and allowed to settle while the centrifuge was run a few minutes. The supernatant liquid was then poured out of the centrifuge tube and the process repeated until the liquid in the centrifuge tube gave no test for chlorine with silver nitrate. Care was taken to run the centrifuge each time long enough to throw down all silt particles. Since in this determination the clay is determined by difference, any clay remaining in suspension was discarded. The portion of the sample in the tube was then washed back into the bottle and the alkali added.

rubbing it is necessary to pour off practically all of the supernatant liquid and it is very difficult to do this from a mortar without losing some sand. Even if this difficulty were overcome, the results on this and on several other samples indicate that the silt fraction is not completely dispersed. However, this method is very rapid for determining the sand fraction and where the clay fraction may be determined empirically as suggested by Davis (1), will give very satisfactory results.

Where no preliminary treatment with acid is given as in Methods A, C, and D, it may be noted that much greater dispersion is obtained by the use of Na_2CO_3 or NaOH than by the use of ammonia. However, after the acid treatment as in Methods G and H there is practically no difference.

The length of time the samples were shaken appeared to have very little effect. Shaking for 2 hours is probably sufficient. In this laboratory, however, it is necessary to run the shaking machine at night so the period may be extended to 7 hours without any inconvenience.

COMPARISON OF METHODS

Several of the methods described above involve too much manipulation to be satisfactory for routine determinations. Since there was so little variation in the results by Methods C to H, it was decided to take the two simplest methods, namely C and F, together with Method A and compare

TABLE 2.—Description of samples

Sample Number	County	State	Type of soil	Depth in inches
372730	Cheyenne	Nebraska	Laural very fine sandy loam	0–10
234847	Bertie	N. Carolina	Wickham silt loam	0–8
560809	Yamhill	Oregon	Sites clay loam	0–12
431911	La Salle	Louisiana	Waverly silty clay loam	0–10
243107	Horry	S. Carolina	Coxville loam	0–12
575233	Brawley	California	Holtville silt loam	0–30
272021	Mahoning	Ohio	Mahoning silty clay loam	0–6
415905	Morgan	Alabama	Pope silty clay loam	0–10
242925	Marlboro	S. Carolina	Marlboro sandy loam	6–11
100407	Aroostook	Maine	Easton loam	8–36
415913	Morgan	Alabama	Decatur fine sandy loam	0–8
234815	Bertie	N. Carolina	Dunbar fine sandy loam	0–10
312611	Wanpoia	Wisconsin	Poygan fine sandy loam	0–12
351748	Traill	N. Dakota	Webster silt loam	0–10
243150	Horry	S. Carolina	Dunbar fine sandy loam	20–36
480308	Fort Laramie	Wyoming	Orella clay (poorly drained phase)	8–36
431958	La Salle	Louisiana	Montrose silty clay loam	7–36
234715	Beaufort	N. Carolina	Coxville very fine sandy loam	7–36
450858	Canadian	Oklahoma	Lincoln clay	0–6
415930	Morgan	Alabama	Colbert clay	8–36

the results on a number of different samples. The samples selected for this work are described in Table 2. These samples were selected by an arbitrary plan from more than two hundred samples upon which determinations of mechanical analysis by Method A and the moisture equivalent were available. The results of the analyses are given in Table 3.

These results indicate wide variation in the degree of dispersion obtained by the different methods in different soils. The analyses of sample 431958 are practically identical by the three different methods, while the analyses of sample 351748 show wide variations in all groups. In general, the greatest variations occur in those samples noted as containing $CaCO_3$ and the greatest degree of dispersion in these samples is obtained by Method F, since the acid treatment removes the $CaCO_3$ and the consequent flocculating action. With the samples containing no calcium carbonate, there is little to choose between Methods C and F. Method C seems to be superior to Method A particularly with samples containing calcium carbonate. A careful examination of the results shows, however, that a fixed and definite method of procedure can not be rigidly adhered to in making mechanical analyses of all types of soils. This is well illustrated in sample 560809, with which none of the three methods was effective in bringing about complete dispersion, but rubbing had to be resorted to as well. While Method F is more effective than any other single method and in practically all cases will give complete dispersion, samples under analysis should be examined to see if complete dispersion has been effected.

THE COLLOID DETERMINATION IN MECHANICAL ANALYSIS

In determining the quantity of colloid by water adsorption a great similarity was noted between the quantity of colloid and the quantity of clay obtained by mechanical analysis using Method F. Theoretically the quantity of clay should be greater than the quantity of colloid owing to the mineral particles between 0.005 mm. the upper limit of clay and 0.001 mm. the upper limit of colloid. Practically, however, the colloid is never completely dispersed in the mechanical analysis and the determination of the quantity of colloid is subject to a possible variation in the average factor as pointed out by Robinson (6). The quantity of colloid in the samples listed in Table 2 was determined and a comparison of these results with the quantity of clay in the samples as indicated by Method F in Table 3, is made in Table 4.

The results indicate the close agreement in general between the quantity of clay and the quantity of colloid over a range from 4 to 70 per cent. The coefficient of correlation was found to be $+.96$ while the probable difference of any single determination as indicated in the table, is ± 4.4 per cent.

When this method is used to determine the quantity of clay and the sand is determined separately as in Method B, it is a simple matter to

TABLE 3.—Comparison of methods of mechanical analysis

Sample Number	Method	Sand	Silt	Clay	Class
372730 [a]	A [b]	47.0	43.8	9.2	Loam
	C	49.4	36.1	14.5	Do
	F	46.3	29.7	24.0	Clay loam
234847	A	32.8	49.2	18.0	Loam
	C	32.6	46.9	20.5	Clay loam
	F	36.7	43.5	19.8	Loam
560809	A	35.7	58.7	5.6	Silt loam
	C	23.4	42.5	39.1	Clay
	F [c]	26.4	31.3	42.4	Do
431911	A	10.7	71.8	17.5	Silt loam
	C	9.7	68.4	21.9	Silty clay loam
	F	10.9	64.6	24.5	Do
243107	A	47.3	32.7	20.0	Clay loam
	C	48.5	31.1	20.4	Do
	F	49.2	28.6	22.2	Do
575233 [a]	A	27.4	44.0	28.6	Clay loam
	C	20.0	40.9	39.1	Clay
	F	19.2	30.2	50.6	Do
272021	A	26.7	50.7	22.6	Silty clay loam
	C	30.7	47.0	22.3	Clay loam
	F	28.4	47.5	24.1	Do
415905	A	11.4	67.8	20.8	Silty clay loam
	C	13.2	63.1	23.2	Do
	F	12.0	61.0	27.0	Do
242925	A	76.5	15.9	7.6	Sandy loam [d]
	C	77.4	14.0	8.6	Fine sandy loam
	F	76.1	14.0	9.9	Do
100407	A	61.0	28.8	10.2	Sandy loam
	C	65.0	25.5	9.5	Do
	F	60.7	26.7	12.6	Do
415913	A	70.0	21.6	8.4	Fine sandy loam
	C	69.5	22.0	8.5	Do
	F	62.7	25.2	12.1	Do
234815	A	77.7	19.0	4.3	Do
	C	78.0	18.6	3.4	Do
	F	79.5	16.8	3.7	Do

[a] Contain $CaCO_3$.

[b] Determinations by Method A in this table were made in the mechanical analysis laboratory of the Bureau of Soils. All other determinations by Middleton.

[c] Owing to the peculiar nature of the colloid in this sample, the aggregates were not entirely broken up by this treatment and in order to get complete dispersion it was necessary to resort to rubbing. However, this analysis is the result by Method F alone. The corrected analysis is sand 1.8, silt 21.8, and clay 76.4 and is used in the calculations later in this paper.

[d] The sand group was separated where necessary to complete the classification.

TABLE 3 (Continued).—Comparison of methods of mechanical analysis

Sample Number	Method	Sand	Silt	Clay	Class
312611	A	54.8	30.0	15.2	Fine sandy loam
	C	54.6	26.8	18.6	Do
	F	56.7	22.7	20.6	Do
351748 [a]	A	53.3	31.7	15.0	Do
	C	40.0	34.3	25.7	Clay loam
	F	28.6	27.0	54.4	Clay
243150	A	70.8	7.6	21.6	Sandy clay
	C	70.9	7.1	22.0	Do
	F	70.2	6.6	23.2	Do
480308 [a]	A	53.2	12.4	34.4	Do
	C	52.7	9.2	38.1	Do
	F	49.5	7.9	42.6	Clay
431958	A	16.2	42.4	41.4	Do
	C	15.2	43.0	41.8	Do
	F	17.4	41.6	41.0	Do
234715	A	14.9	33.6	51.5	Do
	C	11.7	30.3	58.0	Do
	F	11.0	28.6	60.4	Do
450858 [a]	A	21.7	37.8	40.5	Do
	C	16.0	30.9	53.1	Do
	F	15.5	24.6	59.9	Do
415930	A	16.2	23.3	59.5	Do
	C	14.8	16.5	68.7	Do
	F	15.6	15.6	68.8	Do

[a] Contain $CaCO_3$.

complete the mechanical analysis by determining the quantity of silt by difference. This procedure was followed with the above samples except that the quantity of sand was taken from Table 3. A comparison of the results by this method with the results by Method F in Table 3, is shown in Table 5.

It may be noted that the classification of the samples is the same by both methods with three exceptions, 372730, 272021 and 312611, and in these cases the change is slight. The results indicate that very close agreement may be obtained by these methods. The centrifugal method is perhaps to be preferred in general on account of the greater simplicity but in special cases such as sample No. 560809 where the colloid is very difficult to disperse, the adsorption method is of great advantage.

PREPARATION OF SOIL MATERIAL FOR MECHANICAL ANALYSIS BY ELECTRO-DIALYSIS

The mechanical analysis of a sample of Sharkey clay which had been electro-dialysed by Dr. S. E. Mattson of this Bureau was determined by

TABLE 4.—Comparison of the quantity of clay by mechanical analysis and the quantity of colloid by water adsorption

Sample Number	Clay	Colloid	Difference
	per cent	per cent	
372730	24.0	33.0	9.0
234847	19.8	17.0	−2.8
560809	76.4	68.6	−7.8
431911	24.5	22.8	−1.7
243107	22.2	21.3	−0.9
575233	50.6	33.9	−17.7
272021	24.1	16.0	−8.1
415905	27.0	22.9	−4.1
242925	9.9	8.0	−1.9
100407	12.6	7.5	−5.1
415913	12.1	7.7	−4.4
234815	3.7	5.6	1.9
312611	20.6	31.6	11.0
351748	54.4	53.6	−0.8
243150	23.2	25.8	2.6
480308	42.6	45.3	2.7
431958	41.0	41.8	0.8
234715	60.4	54.8	−5.6
450858	59.9	55.0	−4.9
415930	68.8	73.0	4.2
Probable difference of a single determination			±4.40

adding 100 cc. of 0.1 N NaOH to 5 g. of the sample in an 8 ounce nursing bottle, shaking 7 hours, and separating in the usual way. This is designated as Method K in Table 6 where the results by this method are shown together with the results by Methods A and F on samples of the original material.

These results indicate that in this instance preparation of the sample for mechanical analysis by electro-dialysis is just as effective as treatment with acid. However, it is questionable if the process could be simplified to the extent necessary for rapid routine determinations.

MECHANICAL ANALYSIS OF INTERNATIONAL TEST SAMPLES

The samples sent to this laboratory by the First Commission of the International Society of Soil Science were prepared for analysis according to the prescribed directions and analyzed by the centrifugal method used in this laboratory with proper allowances for the difference in the sizes of the fractions. The English-Hissink [1] Method yielded the greatest amount of

[1] **English-Hissink Method.** 5 g. of soil are placed in a beaker with 50 cc. of 20 per cent H_2O_2 and allowed to stand over night. The following day it is boiled for 30 minutes,

TABLE 5.—Comparison of mechanical analyses by the centrifugal (F) and the adsorption (W) methods

Sample Number	Sand	Method	Silt	Clay	Class
	per cent		per cent	per cent	
372730	46.3	F	29.7	24.0	Clay loam
		W	20.7	33.0	Clay
234847	36.7	F	43.5	19.8	Loam
		W	46.3	17.0	Do
560809	1.8	F	21.8	76.4	Clay
		W	29.6	68.6	Do
431911	10.9	F	64.6	24.5	Silty clay loam
		W	66.3	22.8	Do
243107	49.2	F	28.6	22.2	Clay loam
		W	29.5	21.3	Do
575233	19.2	F	30.2	50.6	Clay
		W	46.9	33.9	Do
272021	28.4	F	47.5	24.1	Clay loam
		W	55.6	16.0	Silt loam
415905	12.0	F	61.0	27.0	Silty clay loam
		W	65.1	22.9	Do
242925	76.1	F	14.0	9.9	Fine sandy loam
		W	15.9	8.0	Do
100407	60.7	F	26.7	12.6	Sandy loam
		W	31.8	7.5	Do
415913	62.7	F	25.2	12.1	Fine sandy loam
		W	29.6	7.7	Do
234815	79.5	F	16.8	3.7	Do
		W	14.9	5.6	Do
312611	56.7	F	22.7	20.6	Do
		W	11.7	31.6	Sandy clay
351748	28.6	F	27.0	54.4	Clay
		W	17.8	53.6	Do
243150	70.2	F	6.6	23.2	Sandy clay
		W	4.0	25.8	Do
480308	49.5	F	7.9	42.6	Clay
		W	5.2	45.3	Do
431958	17.4	F	41.6	41.0	Do
		W	40.8	41.8	Do
234715	11.0	F	28.6	60.4	Do
		W	34.2	54.8	Do
450858	15.5	F	24.6	59.9	Do
		W	29.5	55.0	Do
415930	15.6	F	15.6	68.8	Do
		W	11.4	73.0	Do

cooled, 50 cc. H_2O_2 added and boiled for 15 minutes. When cool, 100 cc. of 0.2 N HCl are added in addition to the quantity of HCl necessary for the decomposition of the carbonates. When the reaction is finished 100 cc. of 0.2 N HCl are added and boiled 15 minutes. The sample is washed free of acid and then separated using 0.1 N NH_4OH for the dispersion medium.

dispersion in every instance and in our opinion is to be preferred in cases where it is essential to carry the dispersion as far as possible.

The samples were also analyzed by Method F, for purposes of comparison. The results by the English-Hissink, Official British,[1] and F Methods are shown in Table 7.

The striking thing about these results is the close agreement by the three methods. Fraction I is slightly larger in each case by the English-Hissink

Table 6.—Mechanical analysis of Sharkey clay

Method	Sand	Silt	Clay
	per cent	per cent	per cent
A	31.6	32.8	35.8
F	5.1	31.7	63.1
K	4.7	31.5	63.8

Method but the average difference between the maximum and minimum quantity of Fraction I is only 2.8 per cent for the three methods. The greatest difference in the quantities of Fraction I is in the case of the Badob by the English-Hissink and Official British Methods which is 5.6 per cent. The quantity of colloid as determined by water adsorption is shown in the table for the purpose of indicating again its close relationship to the amount of clay.

GENERAL DISCUSSION

It was pointed out at the beginning of this paper that some form of chemical treatment is now considered necessary in order to obtain complete dispersion for mechanical analysis. The chief objection to chemical treatment is the danger of dissolving a portion of the soil material. This objection, however, may be largely overcome by a proper choice of treatment except in extreme cases. In this work no account was taken of organic matter, carbonates, or the quantity of material dissolved, owing to the fact that the primary purpose of the investigation was to determine a method suitable for routine determinations. However, we realize that for exact determinations of the ultimate mechanical analysis it is necessary to take these factors into account.

The theory of the dispersion of soil material for mechanical analysis is intimately associated with the theory of the dispersion of soil colloids, since once the colloidal material is dispersed the mineral grains may easily be separated.

[1] Official British Method. This method is quite similar to the English-Hissink Method the main differences being that 6 per cent H_2O_2 is used instead of 20 per cent and after the acid has been removed the sample is shaken for 24 hours in 10 per cent NH_4OH and separated with water.

TABLE 7.—Comparison of methods of mechanical analysis on international test samples

Sample	Per cent colloid	Method III, English-Hissink				Method IV, Official British				Method F			
		I[a]	II	III	IV	I	II	III	IV	I	II	III	IV
Podsol, Zdar	31.9	29.7	18.5	37.5	14.0	27.3	19.8	38.6	14.3	28.4	18.8	38.6	14.2
Rendzina, Cejc	30.6	35.5	10.3	46.5	7.7	35.3	10.9	45.5	8.4	34.2	12.0	45.4	8.5
Alkali, Hartobagy	32.4	31.8	20.8	46.4	1.0	29.9	21.1	47.7	1.3	30.7	20.6	47.4	1.3
Badob, Khartoum	72.3	67.2	13.8	17.2	1.9	61.6	15.6	19.6	3.2	64.7	13.6	17.0	4.6
Carrington, Iowa	15.6	16.5	6.7	39.3	37.6	16.0	7.0	38.7	38.3	15.5	7.1	39.0	38.4
Houston, Texas	40.4	38.0	7.0	52.5	2.6	36.2	8.2	53.2	2.4	33.7	11.7	52.2	2.4

[a] Limiting sizes of fractions: I <0.002 mm. II 0.002–0.02 mm. III 0.02–0.2 mm. IV 0.2–2.0 mm.

The colloidal material is highly adsorptive and adsorbs from the soil solution many complex ions which tend to neutralize the charges on the individual particles so that they tend to coalesce and form aggregates. In order to disperse these aggregates it is necessary to remove the adsorbed ions and substitute an ion which will impart the same charge to all particles thus tending to make them separate, since like charges repel each other. The function of the acid treatment is to remove the adsorbed ions so that when the alkali is added later the colloidal particles may all be dispersed. Work on a limited number of samples has shown that electrodialysis performs the same function.

In this investigation it was found that treatment for 1 hour with cold 0.1 *N* HCl was sufficient. In extreme cases boiling with acid may be more effective but there is the danger of dissolving more of the soil material.

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THE MECHANICAL ANALYSIS OF SOME SCOTTISH SOILS

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Dr. Ogg, in his paper,[1] has separated soil profiles in Scotland into three main groups classified on a rainfall basis. These groups are:

(1) Soils of the driest regions.
(2) Soils of moderate rainfall regions.
(3) Soils of the high rainfall region.

Group 2 is further sub-divided into:

(a) Soils similar to Group 1 but having a greater tendency to grey layer formation under the peat; soils showing a glei horizon owing to temporary or permanent marsh conditions:

(b) Soils having a more pronounced grey layer than (a) and characterized by pan formation.

The mechanical analyses of the successive layers of four soils falling into these different groups have been carried out and the results tabulated in the accompanying tables. Soil 601 comes from the lowest rainfall region and is probably a Brown earth; soils 548 and 567 fall in the moderate rainfall group, the latter showing a glei horizon; while soil 553 comes from the Lammermuir Hills where the rainfall is 40 inches or more.

The actual analyses were carried out using the new British method, i.e. a pre-treatment of the sample involving the use of hydrogen peroxide and 0.2. *N* HCl followed by, at least, a 12 hours' shaking of the ammoniacal suspension in an end-over-end shaker and the subsequent performance of the analysis by the pipette method. In the case of soils 601 and 567 the suspensions were sampled a sufficient number of times to allow of a graphical representation of the mechanical composition of the layers of the profile. The amounts of SiO_2, Fe_2O_3 and Al_2O_3 brought into solution, in the case of these two soils by the hydrochloric acid used, were estimated.

In the tables the results for soils 601 and 567 are given for both the British and International groupings, the figures on the British being based on the ignited weight while those on the International were determined at 105° C. Analyses for soils 548 and 553 included the ignited weights only. In order to bring out more accurately any differences in the size distribution of the mineral matter of the different layers of the profile, figures for the fractions have all been calculated to a 100 per cent ignited

[1] Commission V, First International Soil Congress, Washington, D. C., 1927.

weight of soil and the tables containing these figures set out immediately below the corresponding table containing the actual figures of the analyses.

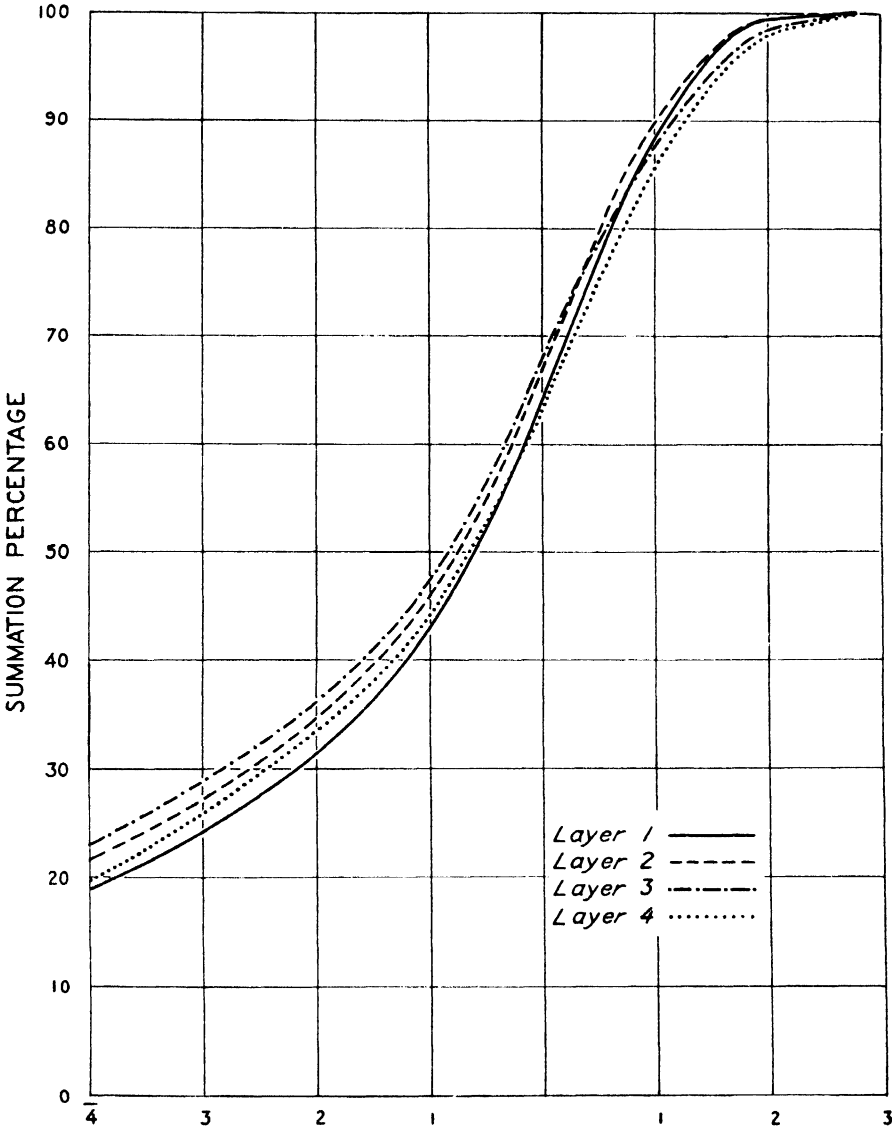

FIGURE 1.—Soil 567. Size distribution of mineral matter

The graphs of soils 601 and 567 have been drawn (after G. W. Robinson) from figures calculated to the ignited soil (figs. 1 and 2). The soils have a pH lower than 7 in all their layers.

In all four soils there is evidence of a layer of accumulation below the surface layers, usually at a depth of from 8 to 12 inches. This accumula-

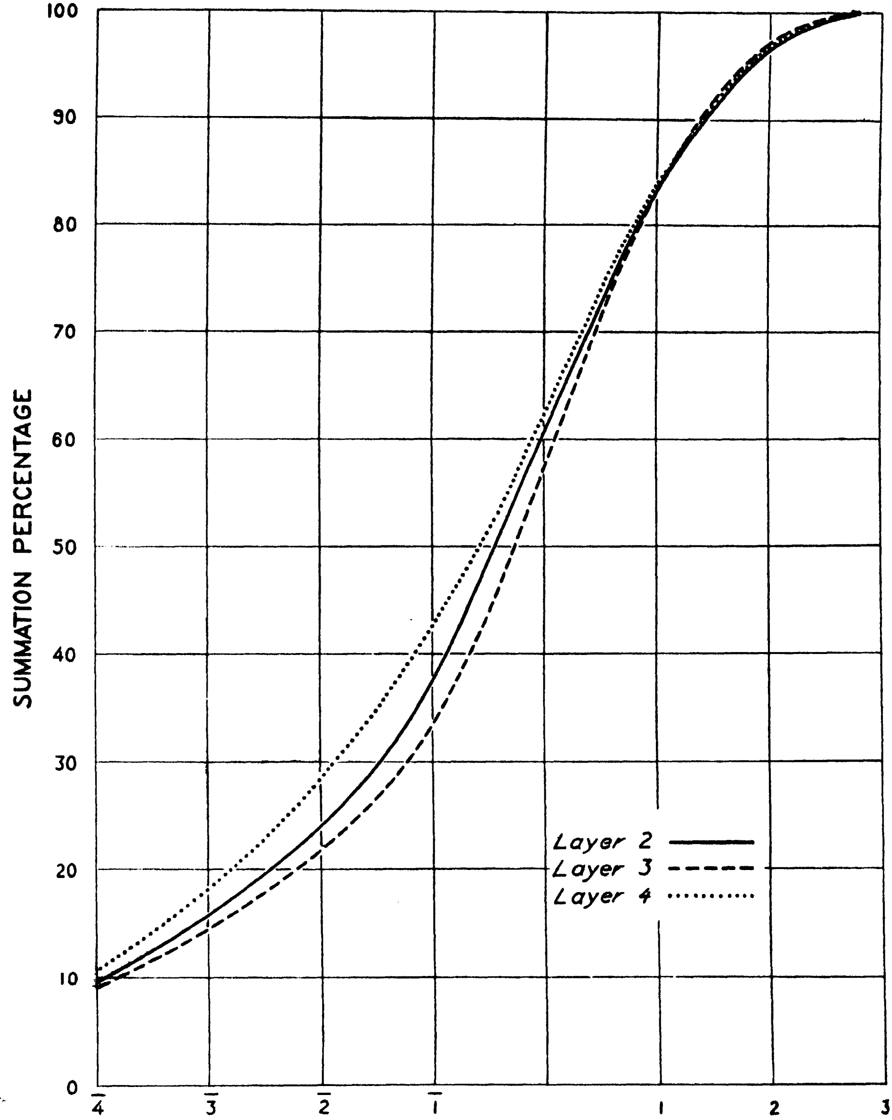

FIGURE 2.—Soil 601. Size distribution of mineral matter

tion is least evident with Brown earth soil 601 and soil 567, greatest in the case of the cultivated Boghall soil 548, and quite considerable in the soil from the highest rainfall group.

In the case of another Brown earth soil from Dunbar which is alkaline in reaction in all its layers, the surface containing 15 per cent of carbonate (as $CaCO_3$) there appears to be hardly any alteration in the mechanical composition of the different layers of the profile. (The mechanical analysis of this soil is not yet completed.)

TABLE 1.—Soil 567. Mechanical analysis of virgin profile (Moffat Wood)

Layer No.	(1)	(2)		(3)		(4)		(5)	
Depth of layer	0 2 in.	2 3 in.		3 8 in.		8 24 in.		24 in.	
		B.S.[a] Ignited weight	I.S.[a] 105°C.	B.S. Ignited weight	I.S. 105°C.	B.S. Ignited weight	I.S. 105°C.	B.S. Ignited weight	I.S. 105°C.
Fine gravel		1.01		1.04		1.64		1.85	
Coarse sand		17.93	20.48	18.50	21.73	18.34	23.39	19.52	28.12
Fine sand		28.76	31.50	29.73	36.50	28.79	33.00	30.08	29.50
Silt		8.57	30.50	8.90	11.70	8.98	12.60	8.63	14.00
Fine silt		10.31	21.00	12.20	25.30	12.13	28.40	13.94	24.00
Clay		15.00		19.45		21.38		17.19	
Moisture	8.64	3.63		2.74		2.70		2.49	
Loss on ignition	39.88	14.79		6.70		5.42		4.96	
Loss in 0.2 N HCl SiO_2		0.14		0.13		0.09		0.12	
Fe_2O_3		0.22		0.22		0.21		0.15	
Al_2O_3		1.14		0.64		0.22		0.12	
Color	Brown	Grey-brown		Grey		Grey-yellow		Mixed grey and liver colored	

Rainfall: 30 in.
Geological origin: Carboniferous sandstone (Calciferous).
[a] B.S. = British scale. I.S. = International scale.

Any variations in the amounts of material brought into solution by the hydrochloric acid principally affects the aluminium and is probably correlated with the organic matter present.

TABLE 2.—Percentage amounts of fractions calculated from analysis in Table 1 on 100 per cent ignited soil

Layer No.	(1)	(2)		(3)		(4)		(5)	
		B.S.[a]	I.S.[a]	B.S.	I.S.	B.S.	I.S.	B.S.	I.S.
Fine gravel		1.24		1.16		1.80		2.03	
Coarse sand		21.98	30.00	20.60	24.25	20.10	25.50	21.40	30.00
Fine sand		35.26	35.00	33.10	38.00	31.55	35.30	32.97	33.40
Silt		10.51	13.60	9.91	13.35	9.84	12.90	9.46	13.85
Fine silt	Peat	12.64	21.40	13.58	24.40	13.29	26.30	15.29	22.75
Clay		18.49		21.65		23.43		18.84	

[a] B.S.= British scale. I.S.= International scale.

TABLE 3.—Soil 601. Mechanical analysis of virgin forest profile (Marykirk, Forfarshire)

Layer No.	(1)	(2)		(3)		(4)	
Depth	0–3 in.	3–8 in.		8–12 in.		12–26 in.	
		B.S.[a]	I.S.[a] 105° C.	B.S.	I.S. 105° C.	B.S.	I.S. 105° C.
Fine gravel		3.90		3.67		3.21	
Coarse sand		18.22	24.68	25.31	33.65	17.72	23.87
Fine sand		26.50	30.29	30.46	32.50	31.27	39.50
Silt		10.60	12.50	9.63	12.50	13.15	18.60
Fine silt		10.50	12.30	10.83	13.00	17.35	14.40
Clay		7.25		8.43		8.70	
Moisture	19.12	6.79		3.58		2.96	
Loss on ignition	66.00	12.99		5.83		4.09	
Loss in 0.5 N HCl							
SiO_2		0.18		0.23		0.17	
Fe_2O_3		0.34		0.07		0.08	
Al_2O_3		2.00		1.24		0.71	
Color	Dark brown	Coffee brown organic		Faded red		Indian red when moist	

Rainfall: 28 in. Geological origin: Lower old red sandstone.
[a] B.S.= British scale. I.S.= International scale.

TABLE 4.—Amounts of fractions expressed as percentage of ignited weight, calculated from analysis in Table 3

Layer No.	(2)		(3)		(4)	
	B.S.[a]	I.S.[a]	B.S.	I.S.	B.S.	I.S.
Fine gravel	4.21		3.83		3.20	
Coarse sand	23.29	38.00	25.29	42.00	18.52	31.50
Fine sand	35.54	33.70	38.40	32.55	35.25	35.50
Silt	13.61	15.30	10.54	13.50	14.79	18.00
Fine silt	13.81	13.00	12.42	12.00	17.71	15.00
Clay	9.54		9.52		10.53	

[a] B.S.= British scale. I.S.= International scale.

TABLE 5.—Soil 548. Mechanical analysis of cultivated soil (Boghall, Midlothian)

Layer No.	(1)	(2)	(3)	(4)	(5)
Depth	0–6 in.	6–8 in.	8–20 in.	24 in.	At 5 ft.
Fine gravel	2.38	.91	.56	1.82	8.22
Coarse sand	13.98	8.99	3.62	13.59	23.39
Fine sand	29.71	21.46	15.30	33.02	31.23
Silt	15.80	16.40	15.30	16.33	8.63
Fine silt	15.55	23.05	27.83	12.85	10.53
Clay	13.85	19.25	24.03	15.50	9.85
Moisture	2.55	3.53	4.24	2.81	2.79
Loss on ignition	7.05	7.02	7.91	4.35	3.85
Color	Chocolate-brown	Brownish	Brownish-yellow	Chocolate	Blue-grey

Rainfall: 30 in.
Geological origin: Mixed carboniferous sandstone (Calciferous) and basalt drift.

TABLE 6.—Amounts of fractions expressed as percentages of ignited weight calculated from analysis in Table 5

Layer No.	(1)	(2)	(3)	(4)	(5)
Fine gravel	2.61	1.01	.65	1.96	8.95
Coarse sand	15.32	10.00	4.18	14.60	25.48
Fine sand	32.54	23.82	17.66	35.47	34.01
Silt	17.32	18.21	17.66	17.54	9.40
Fine silt	17.04	25.60	32.12	13.80	11.47
Clay	15.18	21.37	27.33	16.65	10.73

TABLE 7.—Mechanical analysis of Soil 555 (Kidlaw, Lammermuir)

Layer No.	(1)	(2)	(3)	(4)	(5)
Depth	0–3 in.	3–5 in.	5–8 in.	8–14 in.	14 in.
Fine gravel		2.20	13.40	11.11	20.44
Coarse sand		6.90	13.76	4.71	12.53
Fine sand		12.70	27.17	26.29	20.40
Silt		4.75	10.70	11.50	13.95
Fine silt	Peat	6.15	11.10	14.30	14.70
Clay		5.35	5.70	9.95	7.25
Moisture					
Loss on ignition					
Color	Peat	Dark brown	Light to dark grey	Cinnamon or coffee brown	Pale yellow to dark ochre yellow

Rainfall: 40 in.
Geological origin: Lower silurian.

TABLE 8.—Amounts of fractions expressed as percentages of ignited weight calculated from analysis in Table 7

Layer No.	(1)	(2)	(3)	(4)	(5)
Fine gravel		5.78	16.37	12.94	22.90
Coarse sand		18.13	16.81	14.80	14.04
Fine sand	Peat	33.38	33.20	30.62	22.85
Silt		12.48	13.08	13.39	15.63
Fine silt		16.16	13.56	16.65	16.47
Clay		14.06	6.97	11.59	8.12

A FUNDAMENTAL ERROR IN MECHANICAL ANALYSIS OF SOILS BY THE SEDIMENTATION METHOD

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INTRODUCTION

In the study of soils and other finely divided materials, investigators have long recognized the need of a mechanical analysis, a separation of the mass into the several grain sizes and a measurement of the amount of each size present. The methods of mechanical analysis are generally laborious and time consuming and there is little uniformity in the number of grain-size groups or the limits of sizes within the group that have been established by the different investigators.

The importance of the relations between the mechanical composition and other physical properties such as water holding capacity, percolation, plasticity, cohesion, permeability, capillary rise, etc., has spurred investigators to new efforts to develop methods that will be simple, rapid and accurate. Little progress has been made on the first two points, but methods of determining frequency distribution curves have been developed that seem to show a high degree of accuracy. Of these the method developed by Sven Oden (1) and described by him in various papers, has seemed to give promise of best results, especially in the analysis of the finer textured sediments. He suspends a balance pan near the bottom of a cylinder containing a soil suspension and measures the rate of accumulation of the material as it settles on the pan. From the accumulation curve so obtained, a distribution curve, expressing the mechanical composition of the material, can be constructed and the total quantity of particles of any given radius determined. In the calculations the particles are assumed to follow Stokes' Law (2, 3) which expresses the rate of fall of particles through a liquid. This method of analysis apparently assumes that the amount of sediment falling on the balance pan bears the same proportion to the total sediment that the area of the pan bears to the area of the cylinder.

ERROR IN THE ODEN APPARATUS

In 1923 an Oden type of apparatus was built by the junior author in the Soil Technology laboratory at the University of California and numerous analyses of fine sediments have been made. In order to check the accu-

racy of the work, the total sediment that fell on the bottom of the cylinder, as well as that which fell on the balance pan, was carefully determined. When allowances were made for the material that was below the edge of the balance pan at the start of the experiment, the amounts accumulated on the pan and on the exposed portion of the cylinder bottom did not agree with the relative area of each. In every case the proportion of sediment accumulating on the pan was materially less than it should have been, the amount being usually 85 per cent to 95 per cent of the total that should have accumulated.

This error was first ascribed to a "pumping" effect of the balance pan as it moved up and down, and to reduce this movement the arm of the balance was materially lengthened and the contacts so adjusted that the maximum vertical movement of the pan was less than one-tenth millimeter. The movement of the pan was so controlled that its rise, after the addition of a weight to the other arm, was very slow. This adjustment and refinement of the apparatus did not, however, overcome the discrepancy, the error still being present.

When the balance pan was detached and allowed to rest on the bottom of the cylinder, thus eliminating any possibility of a "pumping" effect due to pan movement, the results were practically the same, a larger proportion of the sediment accumulating on the bottom of the cylinder than on the pan surface. In order to further test this uneven distribution and to eliminate possible error due to the presence of the balance pan, an aqueous suspension of clay in a cylindrical vessel was allowed to stand for two weeks. Most of the liquid was then very carefully siphoned off and the remainder allowed to slowly evaporate at room temperatures, the vessel not being disturbed in any way during the entire period. The accumulation of sediment on the bottom of the cylinder was found to be noticeably thicker near the walls of the vessel than near the center. There was a fairly definite ring of sediment on the bottom next to the cylinder walls.

After repeated attempts to overcome this error we have concluded that it is fundamental and inherent in the method and that it is due to the nature of the disperse system of an aqueous solution.

When a soil or an insoluble powder is shaken up in water with a deflocculent the dispersed particles are assumed to carry an electrical charge. In all the experiments we have conducted, the particles always migrate toward the positive pole when under the influence of an electrical potential gradient, indicating the presence of a negative charge on the individual particles. In explaining the results of the sedimentation experiments, we have assumed that a mutual repulsion due to a like charge caused the particles to disperse and spread as far apart as possible. The walls of the containing vessel limit the extent of dispersion in any given plane, but if we assume that no other force intervenes and that all the particles are of the same size, they would ultimately be equally spaced throughout that

plane and, falling at a uniform rate, would give an equal distribution of sediment over the bottom of the cylinder.

If the walls of the containing vessel are assumed to carry a positive charge, particles near the wall will be attracted to it and on contact will become positively charged, as the electrical capacity of the container is greater than the capacity of any individual particle. This positively charged particle will then be repelled from the wall and will be attracted to an adjacent negatively charged particle. The two will cohere and fall to the bottom at a greater velocity due to the increased size of the aggregate.

If the walls of the containing vessel are assumed to be at zero potential, the same result will be obtained. A negatively charged particle will come in contact with the wall and be discharged. This particle, touching some other charged or discharged particle, will cohere and the two will fall as a larger compound particle.

Either condition tends to bring about a depletion of the suspension near the walls of the container. This is counteracted by the movement of the suspended particles toward the walls, both by the natural dispersal processes and by the attraction of the walls of the container. The entire process is continuous, particles coming in contact with the walls, being discharged, cohering with others and falling as compound particles. The net result is the accumulation of flocculated material on the bottom of the cylinder near the walls, with fewer particles accumulating on the rest of the area. *This progressive dispersal in any given plane results in a path of fall of unflocculated particles that is not vertically downward but is more or less diagonal.*

EXPERIMENTAL

Every available method suggested by co-workers or by scientists in other fields was tried in an effort to correct this error. Cylinders of glass, metal, wood and rubber were used, some coated with lead foil, gold foil, varnish or other materials. The material and size of the balance pan was varied. Different deflocculents were used, and suspensions of various fine powders other than soils were analyzed. Some cylinders were arranged as condensers, and others were wired for cataphoresis tests. No satisfactory method was developed, however, all tests proving failures and it is felt that the error is inherent in the method and probably unavoidable.

The cylinders used in all the experiments except a few were 39 cm. high by 12.5 cm. in diameter. They were assembled in rings swung on gimbals, and suspended in a water bath kept at a constant temperature by thermostatic control. The balance pans were hung by three fine silk threads from a triangular yoke which in turn was suspended from the left beam of the balance by a German silver rod with a turnbuckle arrangement to permit of vertical adjustments. In the earlier experiments a

"sockle plate" similar to that used by Oden was placed in the bottom of the cylinder. In later experiments this was omitted.

The balance was so constructed and wired that the depression of the pan by the accumulated load of sediment would close a contact, causing a weight (shot weighing 0.0549 g.) to be dropped on the other pan, at the same time marking a tape on which the time was being recorded at stated intervals. From the data on this tape the rate of deposition of equal increments of sediment could be read and accumulation and distribution curves calculated.

No fixed method of preparing the sample for analysis was adhered to, inasmuch as samples covering a wide range both in texture and chemical composition were studied. In most cases the following procedure was closely followed. A 20 g. sample of the soil was dried for at least 48 hours at a temperature of 60° C. in a desiccated atmosphere, then placed in an 8 ounce bottle with 100 cc. distilled water and the designated amount of deflocculent and shaken for 20 hours.

The sedimentation cylinder was filled with distilled water and left in the thermostat bath until the desired temperature was reached. The depth of the liquid was carefully adjusted and sufficient withdrawn to equal that in the bottle of soil suspension, together with an additional 100 cc. for washing the shaker bottle. Stirring was accomplished by introducing compressed air into the cylinder through a perforated ring tube, inducing an active bubbling through the liquid and an even distribution of the particles at the start. When the sample was added to the sedimentation cylinder and the suspension thoroughly mixed, the compressed air was shut off and the instrument started, the initial time being punched on the tape as time = 0. From this time onward the operation of the apparatus was automatic.

Bubbles of air accumulating under the balance pan caused some errors in these tests and in later experiments the suspension was mixed outside by repeatedly pouring from one cylinder to another, brought to the constant temperature, and when all was ready, was quickly poured into the sedimentation cylinder through a large funnel, the balance pan brought to rest and the instrument started. Many tests were conducted without the use of the balance, the pans being suspended in the cylinders and the system allowed to stand for the indicated time. In these tests no accumulation curve could be obtained; they were conducted solely to determine the distribution of the sediment on the pan and cylinder bottom.

Sedimentation was allowed to continue for a sufficient length of time to insure a fairly complete analysis. The finer the material analyzed, the longer was it necessary to continue the sedimentation. At the completion of the determination, the material in suspension above the upper edge of the balance pan was siphoned off, the pan removed and the material on it

collected, dried and weighed. The material remaining in the cylinder was likewise collected, dried and weighed, due allowance being made in the calculations for the sediment that was below the edge of the balance pan at the start of the experiment. The ratio of the weight of sediment accumulated on the balance pan to the total amount that accumulated on both the pan and cylinder bottom was compared with the ratio that the area of the pan bore to the total area of the cylinder bottom, the result disclosing the efficiency of the experimental method.

Very many determinations were made, all showing the characteristic discrepancy, although once (see test No. 69, Table 2) an efficiency of 99.6 was obtained. When convinced that the uneven distribution observed was not due to lack of skill or to errors in manipulation, definite efforts were made to ascertain the cause and to develop means to overcome it. Tables 1 to 4 show the results of a few of the many tests. Table 1 shows the result of varying the size and composition of the suspension cylinder and the balance pan.

TABLE 1.—Effect of varying the size of pan and cylinder

Number of Test [a]	Composition		Diameter of		Ratio pan to cylinder	Efficiency
	Cylinder	Pan	Cylinder	Pan		
			cm.	cm.		per cent
38	Galvanized iron	Iron	48.70	5.00	1:94.400	83.2
39	Earthenware jar, glazed	Glass	25.70	6.36	1:16.550	86.3
40	Glass	Glass	12.50	6.36	1: 3.885	77.5
41	Earthenware jar, glazed	German silver	25.70	15.10	1: 2.949	86.5
42	Glass-lined inside and outside with lead foil	German silver	12.83	9.05	1: 2.030	82.2
43	Do	Glass	12.83	10.00	1: 1.641	67.8
44	Glass	German silver	15.85	12.75	1: 1.559	82.2

[a] The material used was powdered silica, deflocculated with 10 cc. of ammonia, and allowed to settle for 18 hr.

Ratios of pan area to cylinder area varied from 1:1.559 to 1:94.400 without showing any improvement in the results. Apparently the flocculated material falls only adjacent to the walls of the cylinder and the results are not much affected by varying the ratio of area of pan to cylinder. The results from the use of the large galvanized iron can were especially disappointing, as it was hoped that with a large ratio the discrepancy in results might disappear. Although only one of these tests is reported, many were carried out, all giving comparable results.

Table 2 gives the results obtained from determinations in which wooden

and hard rubber cylinders were used. It was suggested that these might not react so definitely as electrical systems and might give more satisfactory results. Cylinders of heavy wood (lignum vitae), of light wood (poplar) and of semi hard rubber were secured and numerous tests carried out, a few being reported in Table 2.

TABLE 2.—Effect of wood and rubber cylinders

Number of Test	Suspended material	Diameter of Cylinder	Diameter of Pan	Time of settling	Efficiency
		cm.	cm.	hr.	per cent
60	Powdered silica	16.69 [a]	9.05	8.32	88.0
63	Do	16.69 [a]	9.05	48.0	97.8 [c]
64	Willows clay loam 0–4 in. (sands removed)	16.69 [a]	9.05	144.0	84.6 [c]
65	Decanted material from No. 64	16.69 [a]	9.05	504.0	90.4 [c]
68	Willows clay loam 0–4 in.	12.49 [b]	9.05	240.0	69.0
69	Do	12.49 [b]	9.05	456.0	99.6 [d]
70	Do with sands removed	12.49 [b]	9.05	144.0	65.4
71	Decanted material from No. 70	12.49 [b]	9.05	504.0	60.1

[a] The clyinder was of heavy wood with a German silver pan.

[b] The cylinder and pan were both of hard rubber.

[c] Pan placed on bottom of cylinder, not hung in the suspension. The materials were deflocculated with 10 cc. ammonia. In Test No. 63 the suspension was 29.3 cm. deep. The others were 34.0 or 34.3 cm.

[d] This result was never again obtained though repeated trials were made under apparently identical conditions.

The results were exceedingly disappointing, especially those with the rubber cylinder. The only advantage in the use of wood or rubber seemed to be the elimination of breakage of the sedimentation cylinders!

Comparisons of tests No. 64 with No. 65 and of No. 70 with No. 71 show that prolonged settling of the fine sediments does not materially affect the result. Test No. 65 seems to indicate that the finer particles do not migrate to such an extent as those of somewhat larger size, but No. 71 does not bear this out. Detailed accumulation curves show that the migration does not take place when the particles are greater than 17 μ in diameter, and there is some evidence to show that it is not so active when the particles have an effective radius of less than 0.8 μ. The latter point, however, has not been established.

Efforts were directed to the modification of the electrical system of the suspension cylinder, by arranging the cylinder walls as a definite condenser and maintaining certain potential charges on the walls. The results of some of these trials are given in Table 3.

TABLE 3.—Effects of electrical potential

Number of Test [a]	Suspended material	Electrical factors		Time of settling	Efficiency
		Connections	Voltage		
				hr.	per cent
13	Willows clay loam 8-12 in.	Positive pole to outside plate, negative pole to inside plate	7,000 rectified	22.8	85.0
14	Do	Do	Do	19.38	83.1
15	Do	Do	30,000 rectified	1.11	83.0
16	Willows clay loam 0-4 in.	Do	1,000 from motor generator	8.85	81.0
17	Do	Positive pole to inside plate, negative pole to outside plate	Do	2.61	86.5
20	Do	Negative pole to inside by dipping wire into suspension	Do	3.5	86.0
24	Do	Do	Do	2.48	85.0
31	Powdered silica	Do	2,500 rectified	0.872	85.6
29	Do	Positive pole to inside by dipping wire into suspension	Do	1.09	84.4
35	Do	Positive pole to inside plate, negative pole to outside plate	1.5	13.14	83.5
36	Do	Do	110.0	.74	86.7
37	Do	Negative pole to inside plate, positive pole to outside plate	Do	1.22	66.7

[a] The materials were deflocculated with 10 cc. of ammonia, the depth of the suspension was 33.5 in all cases. The pans were of German silver in all tests except No. 29 and No. 31 when glass pans were used. The cylinders were of glass, lined inside and outside with lead foil, except No. 20, No. 24, No. 29 and No. 31 which had the lining on the outside only. The ratio of area of pan to cylinder was 1:1.925 in all tests except No. 29 and No. 31 when it was 1:3.852.

The voltages maintained across the plates of the condenser ranged from 1.5 volts to 30,000 volts, but no improvement in results was obtained. Since the charge in a condenser is considered to be held in the dielectric

and only stray charges found on the actual surface of the condenser wall, it was thought that by removing the inside lining of the vessel and completing the circuit by dipping a charged wire into the suspension, the charge could be more localized on the inside wall of the vessel. Tests No. 20, No. 24, No. 31 and No. 29 show that this arrangement did not improve the results. Test No. 37, as compared with No. 36 shows a reduction in efficiency when the negative pole was connected to the inside plate.

It was suggested that the cause of the migration of particles toward the walls of the container was due to an electrical potential gradient and that if a similar gradient could be established in the opposite direction and of equal strength, this movement of the particles would cease. In order to establish such gradients the cylinders were arranged with a lining of lead foil or gold foil on inside and outside, these connected to the opposite poles of the power source. An electrode of carbon or platinum was suspended in the center of the cylinder, connected with either the negative or positive pole as indicated. A voltage of 220 volts was maintained between the linings of the condenser, while the center electrode received charges of from 0.01 volt to 10.5 volts. The results of some of these experiments are given in Table 4.

Powdered silica was used in all these tests, deflocculated with ammonia (NH_4OH) and allowed to settle for 18 hours. The ratio of the pan area to the cylinder area was 1:1.885. Tests No. 47 and No. 48 gave high efficiencies, partly explained by the movement of particles to the carbon rod and their accumulation in a pile on the pan beneath the end of the rod, and partly to the decomposition of the rod and the accumulation of bits of carbon on the pan. An attempt was made to overcome this disintegration by coating the rod with collodion, but the coating burst and the disintegration continued.

The carbon rod was replaced by a platinum wire, but difficulty was experienced in maintaining the platinum wire in the exact center or axis of the cylinder. If the wire was not exactly centered, the resistance would vary from point to point where the distance from the wire to the walls varied. If a platinum wire or rod of sufficient diameter to be rigid had been available, this difficulty could have been overcome. Tests No. 57 and No. 58 show the results of reversing the polar connections in the cataphoresis tests. A marked lowering in efficiency resulted from connecting the negative pole to the platinum wire, the percentage efficiency dropping from 83.9 to 70.0. While we did not obtain the desired results, we believe that it may be possible to establish a potential gradient from the cylinder wall to an electrode in the center of the vessel that will exactly balance the tendency of the particles to migrate toward the walls.

These experiments are not now being continued in our laboratories, the investigations being indefinitely suspended. The results are presented here as a challenge to those who are using the sedimentation methods of

TABLE 4.—Effects of cataphoresis

Number of Test [a]	Electrical factors		Efficiency
	Connections	Voltage	
			per cent
47	1. Positive pole to carbon suspended in center of cylinder, negative pole to inside plate	1.5	94.4 [b]
	2. Negative pole to inside plate, positive pole to outside plate	220	
48	1. Do	.75	93.1 [b]
	2. Do	220	
49	1. Do	.01	84.0
	2. Do	220	
52	1. Positive pole to platinum wire in center of cylinder	4.5	83.9
	2. Negative pole to inside plate, positive pole to outside plate	220	
56	1. Do	4.5	81.1
	2. Do	220	
57	1. Do	10.5	83.9
	2. Do	220	
58	Same as No. 57, except poles reversed on platinum wire	10.5 220	70.0
55	Negative pole to platinum wire suspended in center of cylinder, positive pole to inside plate	4.5	82.3

[a] The suspended material in all these tests was powdered silica, deflocculated with 10 cc. ammonia, the container was glass lined on inside and outside with lead foil (No. 52 had inside lining of 21K gold foil), the pans were of German silver, and the time of settling was 18 hr. in all cases.

[b] Small deposit dropped from carbon rod, due to its decomposition, causing greater accumulation on the pan.

mechanical analysis. Either the work is inaccurate and faulty or there is a serious and probably fundamental error in the method. The experiments seem to indicate the latter and to demonstrate that fine particles in a suspension tend to migrate to the walls of the containing vessel, and in settling accumulate on the bottom of the vessel with larger amounts adjacent to the walls. Methods of analysis in which only a part of the sediment is collected are subject to this error and the accuracy of the data obtained is open to serious question.

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A MANOMETRIC APPARATUS FOR THE DIRECT DETERMINATION OF SUMMATION PERCENTAGE CURVES IN MECHANICAL ANALYSIS

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INTRODUCTION

Methods for obtaining continuous size-distribution curves of soil and similar suspensions have hitherto been based on determinations of the variation with time of the weight of sediment (Odén) or of the hydrostatic pressure (Wiegner) at a constant depth. The practical value of these methods has been somewhat restricted by the complicated mathematical analysis required to derive the distribution curve from the experimental data. Since the concentration of the suspension during sedimentation is a function of both the depth and the time, the calculation of the amount of particles of a given size involves the evaluation of the second differential coefficient of the observed weights or pressures against time. Whether the rigid mathematical analysis or some simpler geometrical approximation be used, there is inevitably a considerable loss of precision and a magnification of any experimental irregularities, especially where the measurements extend over only a small range, e.g. 1 or 2 cm. in Wiegner's apparatus.

A considerable simplification in the theoretical treatment would be obtained if it were possible to eliminate one of the variables experimentally. In effect this is achieved in the pipette method of sampling for mechanical analysis. This method depends on the fact that the concentration of suspended particles at a given depth (x) after a time (t) is a measure of amount of particles with settling velocities equal to or less than (x/t). The removal of a sample for a direct determination of concentration requires a separate sedimentation for each point on the distribution curve. Since the excess of the density of the suspension over that of water is proportional to the concentration, direct determinations of the variation with time of the density of the suspension at a given depth would provide at once data similar in type to those obtained in the pipette method of mechanical analysis. The difference in hydrostatic pressure between two points separated vertically by a distance which is small compared with the total depth of the sedimenting column may be taken without serious error as the density at a point midway between them. Although the variation in the hydrostatic pressure between such points

during the sedimentation of a dilute suspension is small, it is possible to measure it by means of a highly sensitive micromanometer. An apparatus embodying these principles has been devised in this laboratory. Its application to the continuous mechanical analysis of soil suspensions was demonstrated to the Conference of the First Commission at Rothamsted in October 1926.

DESCRIPTION OF MANOMETER AND METHOD OF OPERATING

The excess of the hydrostatic pressure between two points in the suspension column over that of an equal column of water is obtained by means of a highly sensitive differential liquid manometer. Two points, separated vertically by about 5 cm. near the base of a sedimentation tube (50–80 cm. long), are connected through water in suitable side tubes to the two arms of a U-tube (about 5 mm. internal diameter) containing water and a liquid with a density close to that of water. Aniline, which gives a magnification of about fifty-fold, has proved suitable, though a less soluble liquid would be preferable. During the sedimentation the difference in level of the aniline surfaces in the two tubes is proportional to the density of the suspension midway between the two side arms and is, therefore, directly proportional to the amount of suspended matter, with a settling velocity equal to or less than that given by dividing the depth of this point by the time of the observation.

Figure 1 shows the manometer and lower portion of the sedimentation tube. After a careful cleaning of the U-tube, the whole of the apparatus is first filled with water and then that below three-way taps in the U-tube is replaced by a suitable amount of aniline, together with water containing a very small quantity of sodium hydroxide. The slight alkalinity of the water in contact with the aniline is essential for maintaining a clean and freely-moving aniline-water interface. The zero readings of the aniline are taken with the taps open to the water in the sedimentation tubes. With the taps closed, the water in the sedimentation tube is drawn off and the thoroughly mixed suspension poured in rapidly. The taps are opened and reading of the aniline levels taken at suitable times, either directly from scales attached to them or by means of a cathetometer. The side tubes are joined to the sedimentation tube by internal seals with small orifices with the double purpose of preventing any entry of air during the filling process, and of minimizing any irregularities in the sides of the tube which would interfere with the free vertical fall of the particles. The side tubes are wide and slightly inclined upwards so that the small amount of suspension, which necessarily enters with the movement of the aniline, does not rise above the orifices. After a sedimentation the side tubes may be washed out through the three-way taps without disturbing the aniline.

Readings of the aniline levels are conveniently plotted against the

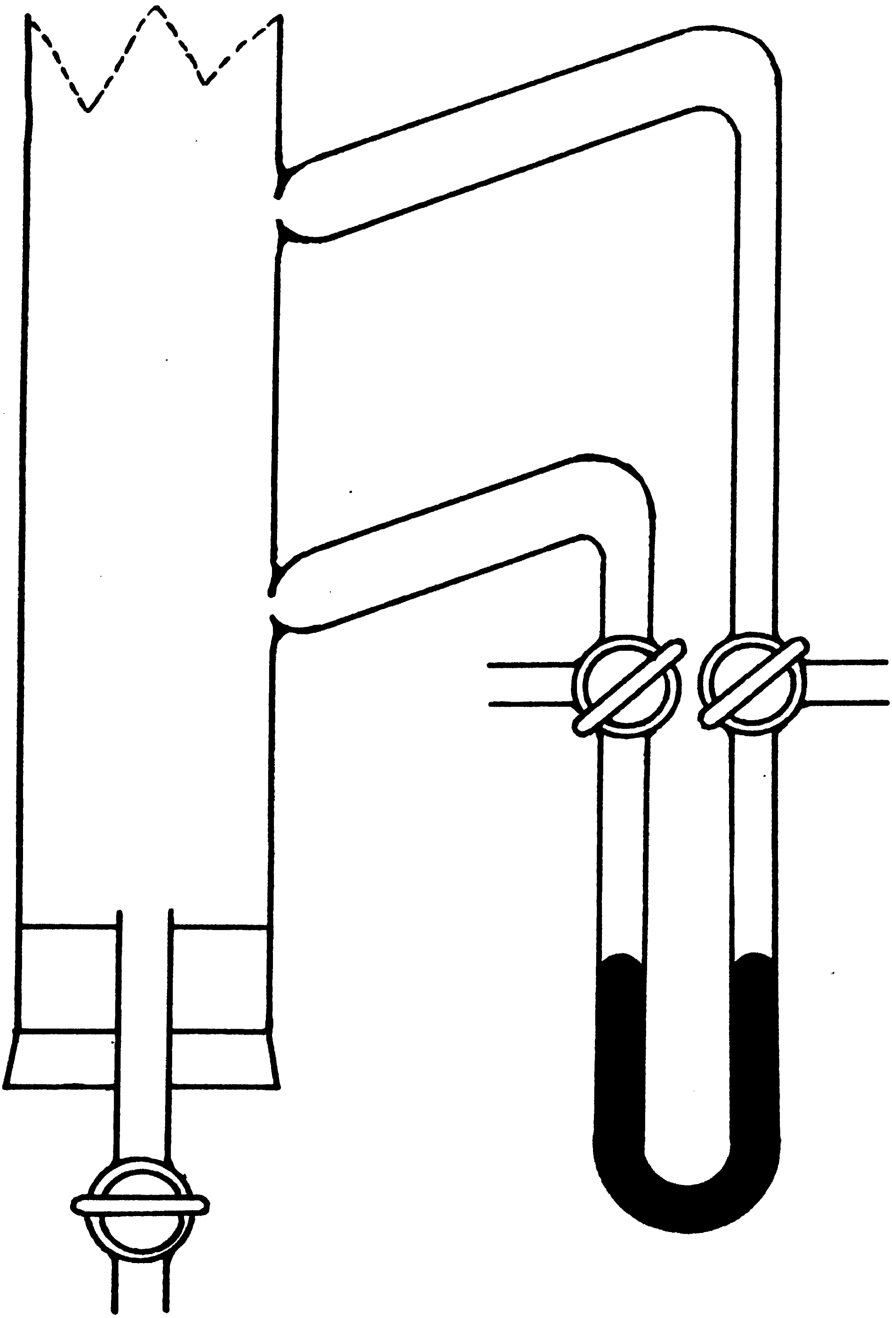

FIGURE 1.—Manometer and lower portion of sedimentation tube

logarithms of the times. A simple adjustment of the logarithmic scale to allow for the length of the sedimenting column converts the curve at once into a summation curve for the logarithms of the settling velocities; a further adjustment of this scale gives the logarithms of the equivalent diameters.

It is sometimes advantageous actually to take the readings at a series of times giving constant increments in log (time).

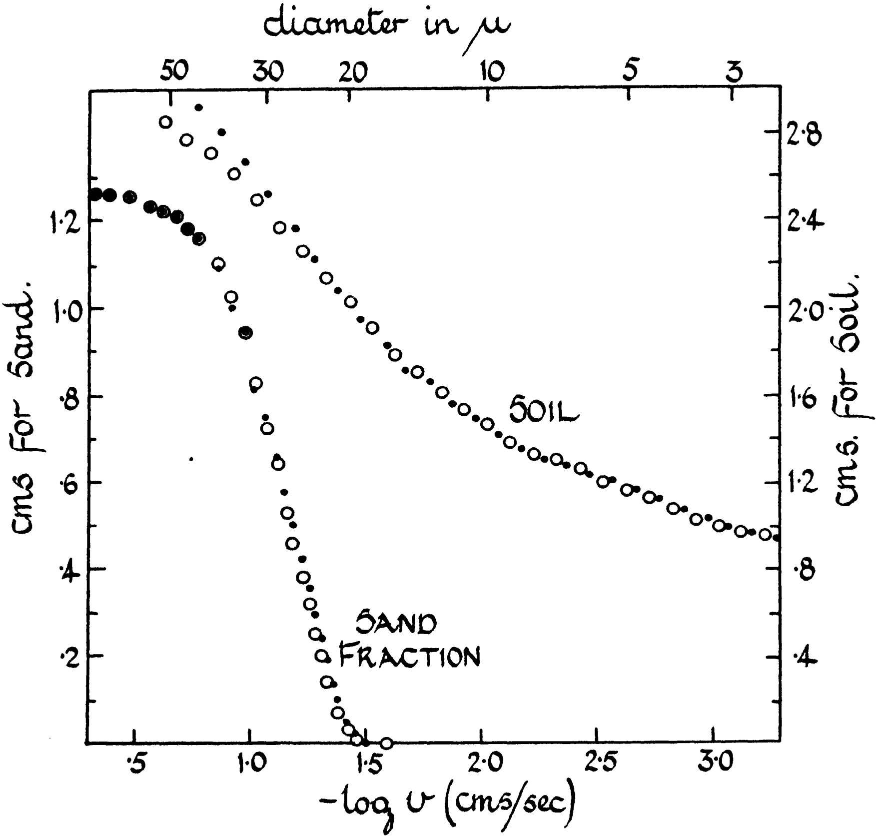

FIGURE 2.—Readings of analine levels plotted against logarithms of the settling velocities. Typical results. A separated sand fraction and a soil

EXPERIMENTAL

Figure 2 gives typical results of duplicate determinations on a separated sand fraction and a soil in sedimenting columns between 40 and 50 cm. long and with the side arms 5 cm. apart. The ordinates represent the actual differences of the aniline levels in cm. plotted against the logarithms of the settling velocities. The sand suspension had a concentration of

1 per cent and gave a maximum value of 1.26 cm. For the soil suspension 20 g. were subjected to the usual pre-treatment methods and made up to 500 cc. after removal of the coarsest fractions by sieving. For convenience in plotting, the ordinates for the soil are given on a scale which is half of that used for the sand. The curves for sand show close agreement throughout; the soil determinations show a divergence during the first few minutes, owing, presumably, to irregularities in transferring the suspension to the cylinder.

The maximum difference of level is reached about 1 minute after filling the cylinder and opening the taps. The readings then remain constant until the largest particles have fallen throughout the whole of the column above the lower side arm.[1]

In suspensions for which this initial constant reading lasts for a few minutes, the apparatus may be standardized and the readings converted into concentrations or percentages by equating the constant initial reading to the known concentration of the suspension. For suspensions in which the largest particles fall so rapidly as to allow no constant initial readings, the standardization is best obtained from separate determinations on some similar suspension, e.g. a silt fraction.

Greater sensitivity may be obtained by increasing the distance between the side arms, or by using a manometric liquid with a density nearer to that of water. Anisole has been employed successfully, after inverting the U-tube, since anisole is lighter than water. The apparatus lends itself to photographic recording on a rotating drum. It may also be used for following the course of flocculation of suspensions or for the determination of size distribution in emulsions, if the manometer is placed near the tip of the column of emulsion.

Where some of the particles are so small as to remain in suspension after a long sedimentation, e.g. with soils and clays, a few further points on the distribution curve may be obtained by slowly drawing off the liquid from the base of the column by means of a capillary tube projecting through the stopper to a point above the sediment. Nephelometric or other concentration measurements on a series of samples from successive depths, yield data for the distribution of density with depth at a constant time from which the size distribution may be simply derived.

[1] It may be noted that in the Odén or Wiegner methods the weight or pressure respectively changes uniformly and at its maximum rate during the period.

NOMOGRAPHS FOR USE IN MECHANICAL ANALYSIS CALCULATIONS

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INTRODUCTION

Although the importance of a temperature correction for the viscosity of water in mechanical analysis has been repeatedly emphasized, the necessary corrections are not in general use. Until recently, standard settling velocities have been defined without reference to a standard temperature, and even in coöperative tests on the methods of mechanical analysis there has been no uniformity in this matter.. Neglect of temperature effects has been justified on the grounds that no great accuracy is claimed for the results of mechanical analysis and that the methods must be sufficiently simple and rapid for use by routine workers. It is suggested that Nomograph A, described below, disposes of the second objection since the corrected values may be read off directly by setting a straight edge across three scales. Recent developments in methods of pre-treatment and of sampling have so greatly increased the accuracy of mechanical analysis that extremely close agreement is obtained in duplicate determinations carried out together. If such satisfactory agreement is to be obtained on different occasions or in other laboratories or countries, temperature corrections will be needed. Such corrections over a normal temperature range will cause only slight displacements of a distribution curve and will make relatively little change when the curve has been fixed by many experimental points. In the more usual case with only three or four points, the changes produced in the individual fractions will be small if the summation percentage curve is almost straight or only slightly curved. But where any one particle size predominates, i.e. where there is a steep portion on the usual summation percentage curve, the small displacement caused by a temperature difference will make a large difference in the amounts of the two fractions divided by a sampling at a point on this steep portion. Such a difference would greatly distort the distribution curve. An illustration of this point is afforded by determinations by the pipette method of the silt and finer fractions at 10 and 20°. The results differed by 4 per cent for a Rothamsted soil, but by 27 per cent for a separated soil fraction; good agreement was obtained in both cases when the corrected settling velocities were used. Again, in the pipette method of sampling the temperature correction is perhaps more necessary than in the older methods of repeated sedimen-

tation, for in the latter case the effect of any abnormally high or low temperature is smoothed out by the further sedimentations. With a single sedimentation there is a possibility of an occasional wide divergence from the normal laboratory temperature.

TEMPERATURE CORRECTIONS

Whatever conclusions are reached as to the connection between particle size and settling velocities, there can be no doubt that the temperature correction must depend on Stokes' Law to the extent that in all determinations the product of the velocity and viscosity should be equal to that given by the standard settling velocity at the standard temperature. In what follows Hoskin's data [1] for the viscosity of water have been employed. The standard temperature is taken at 20° C. as recommended at the Rothamsted Conference of the First Commission.

Table 1 gives the factors by which times or depths of sampling at 20° C. must be multiplied so as to give the equivalent times or depths at some

TABLE 1.—Factors for converting times or depths of sampling into other equivalents

t° C.	Time	Depth
5	1.513	0.661
10	1.303	0.767
15	1.136	0.881
20	1.000	1.000
25	0.888	1.127
30	0.795	1.257
35	0.719	1.392

other temperature t° C. Attention may be directed again to the magnitude of these effects. At 10; *20;* and 30° respectively, equivalent depths are 7.7; *10.0;* 12.6 cm. respectively, and equivalent times for the proposed international fractions, 9¾; *7½;* 6 minutes; and 10 hours, 25 minutes; *8 hours;* 6 hours, 20 minutes respectively. The correction for a few degrees temperature difference is of the same order of importance as a centimeter, a minute or an hour in the three cases illustrated.

Table 1 may be readily extended to give the depths and times for the standard separations at a series of temperatures. It is, however, more convenient to use a nomograph or alignment chart, such as that given in Fig. 1. From this nomograph the corrected values of depth or time at any temperature may be read off immediately, not only for standard values but for all values of depth and time. This is especially useful in connection with the pipette method where it is often convenient to vary

[1] Phil. Mag. 1909, 1: 502; 2: 260.

the values of depth and time whilst maintaining the standard velocity, and especially where it is desired to explore the distribution curve in greater detail by determinations at settling velocities other than the standard ones.

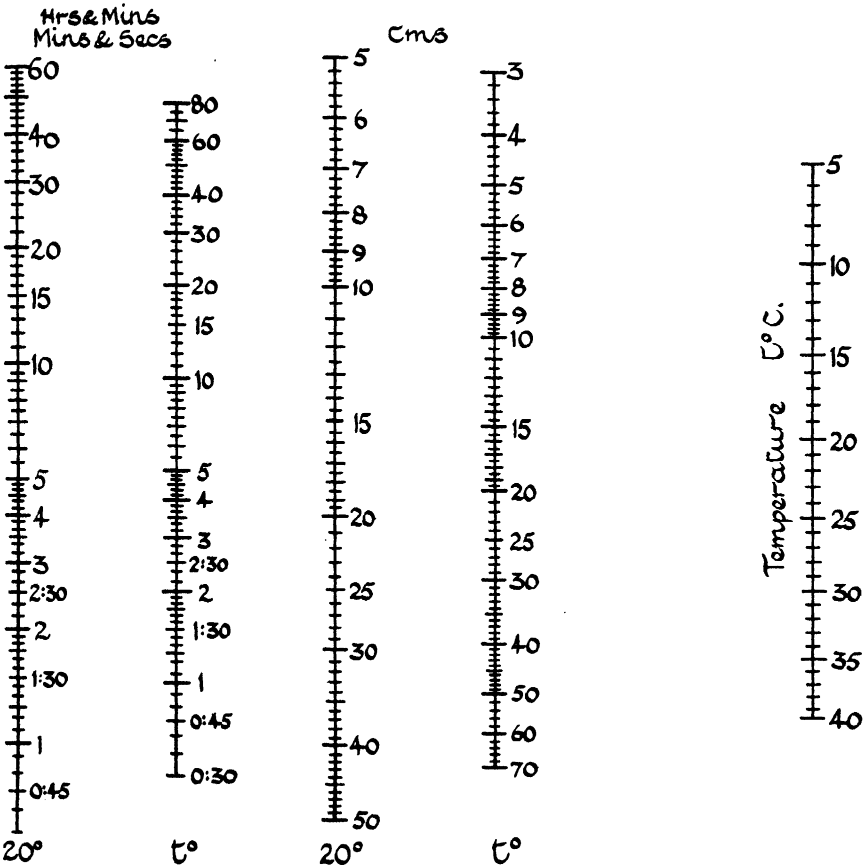

FIGURE 1.—Nomograph A

DESCRIPTION OF NOMOGRAPH A

Nomograph A in Fig. 1 provides for the conversion of any depth (from 5 to 50 cm.) and of any time (from 35 sec. or min. to 60 min. or hr.) at the standard temperature 20° C. into the equivalent values at any temperature from 5 to 40° C. It should be noted that minutes and hours are divided, not into tenths, but into twelfths (5 sec. or 5 min.) up to 2 minutes (or hr.) and into sixths (10 sec. or 10 min.) from 2 to 5 minutes (or hr.). The nomograph is extremely simple and rapid in use. A straight line joining any depth (or time) on the scales marked

20° with the desired value on the temperature scale cuts the depth (or time) scales marked t° at the equivalent value of depth (or time) at this temperature.

The straight line may be obtained by a good ruler or a piece of stretched black cotton but most conveniently by a stout celluloid strip with a black line engraved on its lower surface.

Units in Mechanical Analysis

Other calculations frequently employed in connection with mechanical analysis may be obtained by direct readings from a suitable nomograph. It is becoming increasingly common to express the results of mechanical analysis in the form of summation percentage curves, using as one axis the negative logarithm of the settling velocity ($-\log v$ with v as cm. per sec.).

Again it is often desired to express the results in terms of particle size. Several courses are open in the conversion of settling velocity into particle size. Arbitrary but agreed values may be adopted such as those recommended by the First Commission in its conference at Rothamsted in 1926. Alternatively, each worker may make microscopical measurements on a particular group of soils. Differences in the shape of particles would probably necessitate a separate series of values for each worker and for each group of soils, whilst the method obviously breaks down for the finest particles. The third alternative is to use the "equivalent diameters" deduced from Stokes' Law on the assumption of spherical particles of uniform and constant density (the value 2.7 is assumed below).

For popular presentation of the data from simple routine analysis, the first method is probably the best, whilst the second method may be required occasionally for special investigations. The equivalent diameter is free from any ambiguity of meaning and has been widely used in colloid chemistry.

The use of the settling velocity (or $-\log v$) alone is open to the objection that it is not always clear whether the velocities have been adjusted so as to refer to a standard temperature. The product of velocity and viscosity or ($-\log v\eta$) would avoid such uncertainty, but this quantity has peculiar dimensions. A simple function of this product gives the equivalent diameter, a quantity which is readily visualized.

DESCRIPTION OF NOMOGRAPH B

Nomograph B in Fig. 2 provides for the direct conversion by a single setting of the rule of depths (from 4 to 80 cm.) and times (from 1 min. to 500 hr.) into the corresponding values of $-\log v$ (from 0 to 5.5). For any value of $-\log v$ the required value of depth (or time) can be read off at once for any desired value of time (or depth). This is convenient

for obtaining points between the standard values or for the extremely small settling velocities. For a fixed value of depth it is possible to read off directly a series of values of time giving equal increments in $-\log v$. This simplifies the mathematical analysis of data from continuous

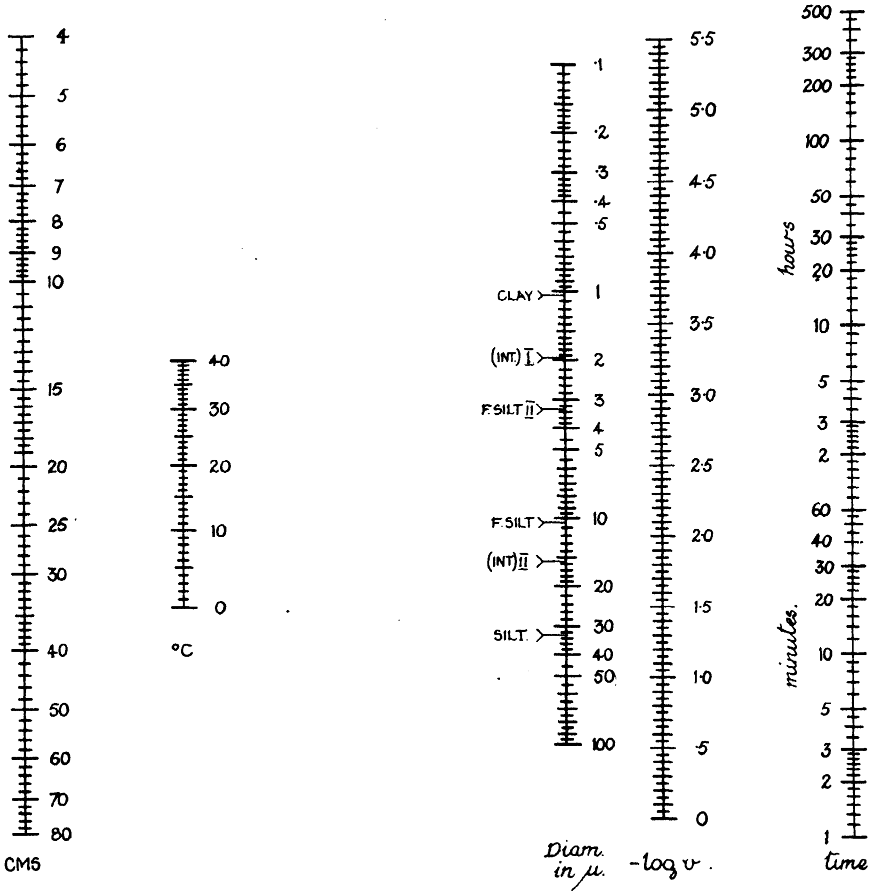

FIGURE 2.—Nomograph B

mechanical analysis methods such as with Wiegner's apparatus or with the one described by the writer in another paper to this Congress.

The three middle lines of Nomograph B provide for the conversion of values of $-\log v$ and temperature (from 0 to 40° C.) into the equivalent diameter in μ (from 0.1 to 100). For convenience the equivalent diameters corresponding to fractions I and II on the proposed international scale, and the fractions Clay, Fine Silt II, Fine Silt I, and Silt on the British scale are marked. It should be noted that these equivalent

diameters differ rather widely from the particle sizes conventionally assigned to these settling velocities.

One setting of the rule converts depth and time into $-\log v$, and a second setting through this value of $-\log v$ and the temperature gives the equivalent diameter. This process may be inverted so as to convert this equivalent diameter into $-\log v$ at some other temperature and thus a new series of depth and time values. As an illustration a line through depth $=10$ cm., time $=8$ hr. gives $-\log v=3.46$; a line through $-\log v=3.46$ and t° C. $=20$ gives the equivalent diameter $=1.95\ \mu$. (This value is marked Int. I). Suppose it were desired to take an equivalent sample at 10° C., then the line through 10° C. and 1.95 μ gives $-\log v=3.57$, and a further setting of the rule gives for 10 cm. a time of 10.3 hours. If it were necessary to sample at a different time, say 6 hours, then the line through 6 hours, and $-\log v=3.57$, gives as the required depth 5.8 cm.

For the simple temperature correction of a known settling velocity Nomograph A is to be preferred as it is both simpler and more accurate. Nomograph B is intended primarily for the convenient interchange of units.

It has been assumed that the temperature remains constant during the sedimentation. Appreciable temperature changes may produce large errors through complex convection currents. Where some fluctuation of temperature cannot be avoided, the mean temperature (or the mean of the maximum and minimum) should be used for purposes of temperature correction.

It is hoped to be able to publish copies of the Nomographs A and B in forms more suitable for withstanding laboratory usage.

A NEW DYNAMOMETER, SUITABLE FOR ALL TYPES OF HORSE AND POWER DRAWN IMPLEMENTS

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INTRODUCTION

In connection with studies of the physical properties of soil the authors have for some years past been making dynamometer measurements of soil resistance, of the draft of cultivation implements, and of soil cultivation processes. The dynamometer used has already been described (1). It was designed for tractor work only, and could not be used for horse traction. Although for much of the experimental work a tractor was found advantageous in that uniform working conditions and comparative absence of personal factors were obtained, it become desirable to extend the enquiry to other forms of traction. A new recording dynamometer has therefore been designed suitable for any form of work from the lightest horse drawn implement to the heaviest form of power cultivation. It is very easily adapted for the different classes of work, weighs only a few pounds, is very robust and simple in construction and can be dismantled, transported, and assembled again, with ease. The continuous record of draft is impressed on a moving strip of celluloid and possesses the very great advantage of immunity to grease, water or dirt. The instrument has satisfactorily undergone extensive trials, and has been employed for some time past in our own work.

The instrument consists of a hydraulic link placed in the hitch of the implement and connected by semi-flexible copper tubing to the recording mechanism that is carried in any convenient position on the implement or the traction unit. The recording mechanism is the characteristic feature of the dynamometer. It consists essentially of the well known Cambridge Instrument Company Stress Recorder, which is designed to record small extensions or contractions of any body to which it is clamped. For the present purpose the feet of this recorder were removed and replaced by two brackets, between which was attached a robust Bourdon tube in the form of an arc.

The instrument in use for horse ploughing is shown in Fig. 1, and a general assembly of the component parts is given in more detail in Fig. 2. Fig. 3 is a diagrammatic drawing of Fig. 2, indicating the salient mechanical features and the electrical connections.

OPERATION OF DYNAMOMETER

Increases in pressure on the oil in the hydraulic link, are transmitted to the Bourdon tube, causing it to straighten and thus alter very slightly in its effective length. As the left end of the tube is rigidly attached to the frame of the Stress Recorder, while the right end is affixed to the lower ends of floating steel pillars, the effect of changes in pressure in the Bourdon tube is to produce a small to and fro movement of the lower ends of the pillars. This movement is transmitted to the recording needle

FIGURE 1.—General view showing dynamometer as used for horse ploughing measurements

through a simple magnifying system of knife edges and levers. The movement of the Bourdon tube is so small that the corresponding movement of the recording needle is proportional to the stress applied to the link, and a linear calibration curve is therefore secured. In order that the instrument may be used for all classes of work, three Bourdon tubes of different strengths were constructed. The weakest is suitable for horse traction, the intermediate one for tractor work, and the strongest tube is employed for heavy operations such as mole drainage, or multiple furrow steam ploughing. The tubes are all of the same external dimensions and easily interchangeable.

The needle marks its trace in the form of a shallow groove on a ribbon of celluloid, 11 mm. wide, that is slowly driven forward by rollers geared

to a clockwork mechanism in the Stress Recorder frame. The clock can be adjusted to various speeds to open out or close up the record, and is started or stopped by an electric control switch carried by the operator. There are also two independent and subsidiary styluses, disposed one on either side of the draft stylus, and operated electromagnetically. One is controlled by a recording clock that closes a circuit every 10 seconds, while the other is controlled by a tapping key, and serves for marking on the chart in the Morse Code, a record of position and any other requisite experimental details and notes. This feature is most useful as it eliminates any danger of confusion in a complicated series of records even if a considerable period elapses before they are examined in the laboratory.

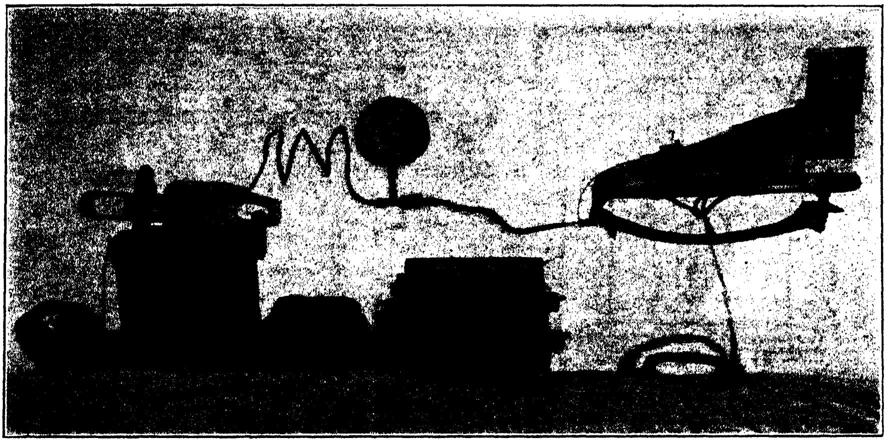

FIGURE 2.—Assembly of the component portions of the dynamometer

The time-clock, switch for controlling the driving clock of the celluloid ribbon, and tapping key for the Morse code circuit, are assembled on the glass fronted panel that is carried by the operator as shown in Fig. 1. The electrical leads from the recorder are combined in a light wire covered cable, terminating in a four-pin plug that engages with a spring socket on the panel. The batteries supplying the current are carried in any convenient position. In the illustration the arrangement for horse traction is shown, the batteries being carried in a leather case, strapped on to the back of the horse. A Bourdon pressure gauge of dial form and calibrated to give direct readings of draft, can be introduced into the oil system at any convenient point. It is used for demonstration purposes, or in cases where a continuous record is not needed.

The assembling of the instrument for an experiment takes very little time. The hydraulic link is placed in the hitch, and the Stress Recorder is strapped to any convenient point, e.g. the beam of the plough, or the back of the tractor. A thick roll of felt and leather straps are most con-

venient for this purpose, as it is necessary to protect the recorder and Bourdon tube from any mechanical shock to which the recording stylus would momentarily respond. The link and recorder are then joined by the flexible copper tubing. This is best employed in short spiral lengths joined by screw unions, in order to facilitate easy connection, as the relative disposition of link and recorder is not always the same. It is advisable to tie the tubing to some support near each of its ends, so that strains due to turning at the headlands are not applied at these points, but are taken up in the spiral parts of the tube. The link, spiral tubing and Bourdon tube are then filled with oil with an oil gun. The usual length of the connecting spiral tube of 4 mm. internal diameter, is about

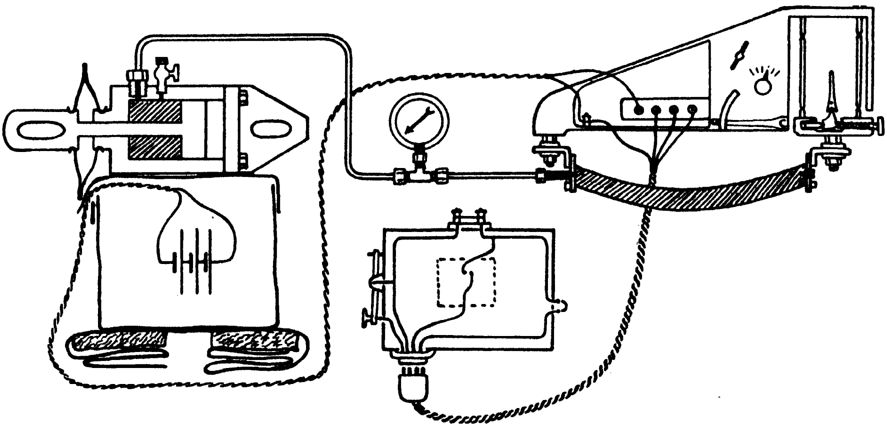

FIGURE 3.—Diagrammatic form of Figure 2 showing mechanical and electrical connections

1.5 m., and for winter work ordinary engine lubricating oil is used. For summer work it is desirable to thicken this with gear oil. When the system is filled with oil, the batteries mounted, and electrical connection made, the operator, carrying the control box on a light harness, is ready to commence work. It is necessary to mark out the area under test beforehand, and to place stakes at convenient places, so that the operator can record by the tapping key the instant of passage past these fixed points. The speed of the clock driving the celluloid ribbon is adjusted to give a chart speed of about 1/4000 of the speed of the implement through the soil. This corresponds to about 1 yard of chart to each 2½ miles of travel. A low power hand microscope is included in the kit, so that the chart can if necessary be examined during the experiment.

The question of chart speed and the allied question of the amount of detail needed on the chart, requires some discussion. With a thin oil, and a high chart speed, a high degree of detail can be secured. For instance, conditions can easily be arranged so that each footstep of the

horse in horse ploughing is very evident on the chart. Conversely, a needle valve on the flexible tubing or the employment of thick oil can be used to damp out fluctuations of draft to any desired extent. This, however, is accompanied by a lag, or delayed response of the recording stylus, and, when carried to the point where all fluctuations are smoothed from the trace, some 20 seconds elapsed between the time of application of the stress to the hydraulic link and the full response of the stylus. This corresponds to a travel of at least 20 yards in horse traction. To get the best chart speed for a compromise between unnecessary detail and undue lag, requires a little experience. For horse traction, the figures already mentioned, which correspond to a chart speed of about 15 mm. per minute, are very suitable.

COMPARISON WITH OTHER DYNAMOMETER

Illustrations of typical and specimen records are shown in Fig. 4. The mole drainage trace, which was obtained with another dynamometer, has been added for comparison. The traces are enlarged facsimile of the original records of horse ploughing, obtained with a low power microscope and a camera lucida. The operation of the time scale and the position marks will be seen from the top illustration, where three time marks are shown on the time trace, and a plot boundary (two dots) with a portion of the word "fallow" in Morse code, are shown on the position trace.

The trace of plough draft is of a different character in the first three illustrations. The top one was obtained in summer with a light oil and is characterized by rapid fluctuations in which a good deal of detail is observed. The second trace shows the result of excessive damping; not only are all fluctuations smoothed out except the larger ones, but a considerable delay occurs between the entry of the plough into the ground and the attainment of the full record.

The third trace shows the best condition for experimental work. The minor fluctuations in soil resistance, that do not appreciably affect the average integrated values, are smoothed out, while the rise of the trace to its correct position is attained in a second or so.

The character of the trace depends on the type of soil. A light sandy soil gives a smoother trace than those obtained in a heavy stony soil. Characteristic portions of records for these two cases are shown in Fig. 4.

An examination of the records clearly shows that the rapid fluctuations observed on the direct reading pressure gauge are real effects. It is quite impossible to take accurate readings from a pointer that is fluctuating over the greater portion of its range, unless the instrument were "damped" very considerably, in which case the time-lag already shown in Fig. 4 would again come in. For large sized plots for which an average value only was needed, this effect would not be serious, but the bulk of experimental work is of necessity confined to smaller sized plots, in which

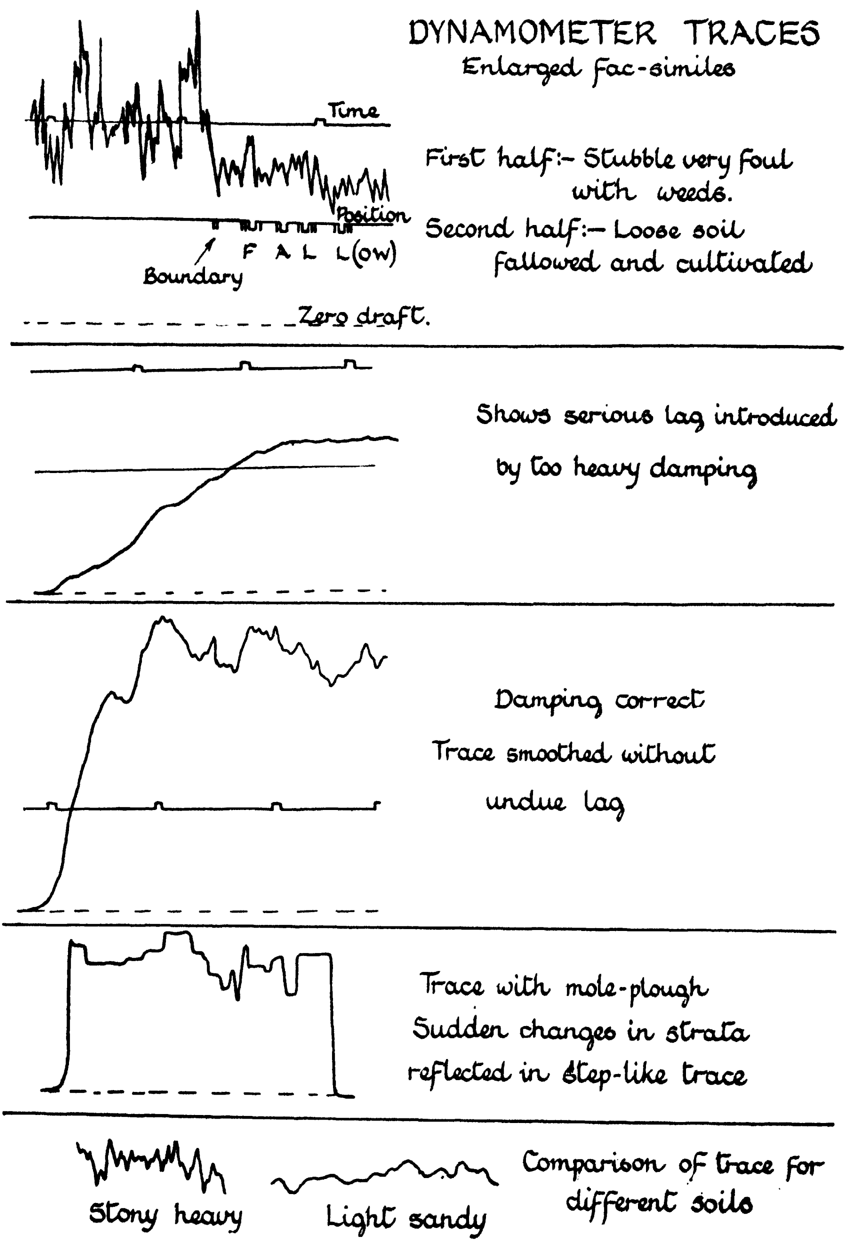

FIGURE 4.—Facsimile records of trace

the coincidence between the recorded resistances and field positions must be fairly close. It follows that some continuously recording mechanism, giving a trace from which average values can be obtained by subsequent integration, must be employed for experimental work.

In working up the experimental records, it has been found most convenient to use a low power microscope with camera lucida attachment, for the purpose of transferring an enlarged image (x 34) of the trace to paper. The chart is worked over a section at a time, and the enlarged image ruled into the appropriate sections as shown by the separate position and time traces. These sections are then integrated with a planimeter—the Conradi Rolling wheel type is found very suitable—and the mean stress obtained. With the chart speed and magnification mentioned it is possible to obtain two sections, each representing about 22 yards of travel, in the field of view of the microscope at the same time.

After a full experience with the dynamometer it can be safely recommended. The great convenience of the celluloid ribbon can only be fully appreciated by those who have had to deal with ink or pencil traces on paper rolls. In the new instrument no setting of the stylus pressure is ever required, and the moving parts are so simple and robust that adjustments have to be made but rarely. In fact, after the connections are made and the record started, the whole conduct of the experiment can be handed over to a routine operator, thus leaving the experimenter free for general supervision, collection of samples, notes, etc.

LITERATURE CITED

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THE VALUE OF THE DYNAMOMETER IN CULTIVATION EXPERIMENTS AND IN SOIL PHYSICS RESEARCH

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INTRODUCTION

The present paper is a summarized account and discussion of experiments that have been carried on at Rothamsted and elsewhere by Dr. W. B. Haines and the writer (2, 3) during the past five years. The experiments have opened up a new method of attack in soil research, and they are being continued in an extended form.[1] The results are not only of direct value in the study of soil; they have also shown that the present method of conducting competitive implement trials is unsound.

The field work originated in an attempt to see whether the long continued manuring of the classical field experiments at Rothamsted had produced any measurable physical effect on the soil. A recording dynamometer was used to measure the resistance offered by the soil of the different plots to the passage of a cultivation implement. The results obtained were at first very puzzling. They were very difficult to reconcile with one another and with other known facts. It was evident that any differences in soil resistance directly due to manuring were being obscured by other causes, which were suspected to be one or both of the following:

(a) The difficulty of obtaining trustworthy readings from a dynamometer under field conditions.
(b) An inherent lack of uniformity in the soil itself causing corresponding variations in the dynamometer readings.

The first alternative was disposed of without difficulty. A reliable dynamometer technique was, in fact, evolved during the preliminary experiments. The full details will be found in the first paper under reference (3). They refer to the "Watson" dynamometer, as used for tractor work, but were proved to apply equally well to the new dynamometer suitable for all types of power (horse or mechanical) that is described in a separate paper (4). The second alternative required careful consideration and examination. The usual criterion for selecting a "uniform" area of land for field experiments or implement trials is the judgment of practical men, which is often supplemented by chemical and physical examination of soil

[1] Further papers in this series are in preparation.

samples, taken at regular intervals over the field. This standard is at the best a qualitative one. It cannot do more than decide whether the land is reasonably level, and free from obvious changes in soil texture. In fact, the fields on which our own dynamometer results were obtained would have been unhesitatingly approved on this standard. Again, apart from the prohibitive amount of labor entailed in making the large number of physical and chemical analyses to supplement a visual judgment, we must recognize that in the present state of our knowledge only general inferences could be drawn from these laboratory tests as to the degree of uniformity of field characteristics. For these reasons it appeared not only justifiable but desirable to use the actual dynamometer measurements of one of these apparently "uniform" fields as a criterion of its degree of uniformity. The experiments were made on a 6-acre area (2.4 hectares) that was level except for one very slight dell. The field had for many years been farmed normally, and had been free from manurial and other experiments. The conclusions that followed the experiment were striking; they have influenced all subsequent work.

The arrangement of the present paper has been influenced by the same considerations. The experiments will be discussed in the following order:

I. Variations of resistance in an apparently "uniform" soil.
II. Persistence of these variations from year to year.
III. Effects of manures on soil resistance.
IV. Relation of the resistance to physical properties of the soil.
V. Relation between soil resistance and crop growth.
VI. Bearing of measurements of soil resistance on implement design and performance.

I. VARIATIONS OF RESISTANCE IN AN APPARENTLY UNIFORM SOIL

The area selected for this work has been described above. The ploughing was done with a two furrow tractor plough on a clover sod that had been twice cut for hay. The method of experiment was as follows: The whole area was marked out in square plots 22 yards wide, and the boundaries in one direction were used as ridges in setting out the ploughing "lands." The work was first about half completed in the ordinary way, then the dynamometer was attached, and two or three furrows recorded around each "land" in turn. Thus records were obtained for a number of furrows spaced at regular intervals across the whole field, i.e. approximately down the middle of each half plot, the direction of ploughing being alternatively up one half plot and down the next. The final average values for the soil resistance for each half plot (22 x 11 yd.) are shown in Table 1. For convenience in reference to individual plots the plot divisions are marked with letters in one direction and numerals in the other.

TABLE 1.—Values of soil resistance (lb.) on a field uniform to visual inspection (Ransome Two-Furrow Plough. Austin Tractor)

Plot		1	2	3	4	5	6	7	8
A	Down	1,236	1,258	1,260	1,282	1,301			
	Up	1,233	1,260	1,275	1,277	1,335	1,383		
B	Down	1,293	1,296	1,282	1,304	1,409	1,428		
	Up	1,231	1,331	1,275	1,262	1,340	1,380		
C	Down	1,257	1,285	1,282	1,270	1,375	1,375		
	Up	1,342	1,287	1,328	1,337	1,456	1,419		
D	Down	1,380	1,337	1,345	1,470	1,529	1,475		
	Up	1,363	1,374	1,356	1,464	1,638	1,712		
E	Down	1,315	1,363	1,349	1,493	1,665	1,575		
	Up	1,378	1,386	1,444	1,544	1,513	1,537	1,500	
F	Down	1,296	1,333	1,368	1,384	1,477	1,507		
	Up	1,263	1,269	1,292	1,317	1,579	1,428	1,441	
G	Down	1,275	1,288	1,317	1,366	1,526	1,370	1,259	
	Up	1,236	1,249	1,294	1,333	1,522	1,394	1,265	
H	Down	1,232	1,246	1,275	1,382	1,329	1,359	1,273	
	Up	1,208	1,241	1,265	1,335	1,362	1,382	1,342	1,310
J	Down	1,158	1,250	1,243	1,263	1,288	1,353	1,328	1,291
	Up		1,082	1,171	1,220	1,250	1,190	1,238	1,209
K	Down		1,174	1,215	1,218	1,225	1,242		

The table shows at a glance that wide variations of resistance occur. The maximum difference is of the order of 60 per cent, ranging from 1,082 lb. on Plot J 2 (up), to 1,712 lb. on Plot D 6 (up). Closer inspection shows a regular variation or drift in the values from one plot to the adjacent ones, the nature of which can best be seen if the results are expressed in graphical form. A scale plan of the field is prepared and the resistance values of each plot are written on it in the center of each plot. Regions of equal value are then joined by a smooth line. A series of curves is thus produced as shown in Fig. 1. This was prepared from Table 1, an interval of 50 lb. between the resistances being taken as the unit. The map has the appearance of an ordinary ordnance contour map, and is read in the same way. The "hills" correspond to regions of high soil resistance, the "valleys" to regions of low resistance, and the "gradient" at any point shows the rate of change of soil resistance. As each "contour" shows a region where the dynamometer readings are constant, the name "isodyne" has been adopted as a convenient description. There is no doubt as to the correctness of the isodyne map of Fig. 1. The dynamometer technique already evolved precluded any possibility of the results being due to causes other than the variations in inherent resistance of the soil. It should be further observed that the convention of plotting the average result for each half plot has automatically smoothed out many minor variations that are legitimate deductions from the data. A calculation of the probable error of the figures for the gradient of the soil resist-

ance from one plot to the next, based on a few comparisons of the individual furrow records, gave values between 10 and 20 per cent. The directions of the gradients or change in resistance from one plot to the next shown in Fig. 1 are therefore always statistically significant and the values of the gradient even on the very limited comparison made are correct to at least one part in five. In a later section details are given of fuller

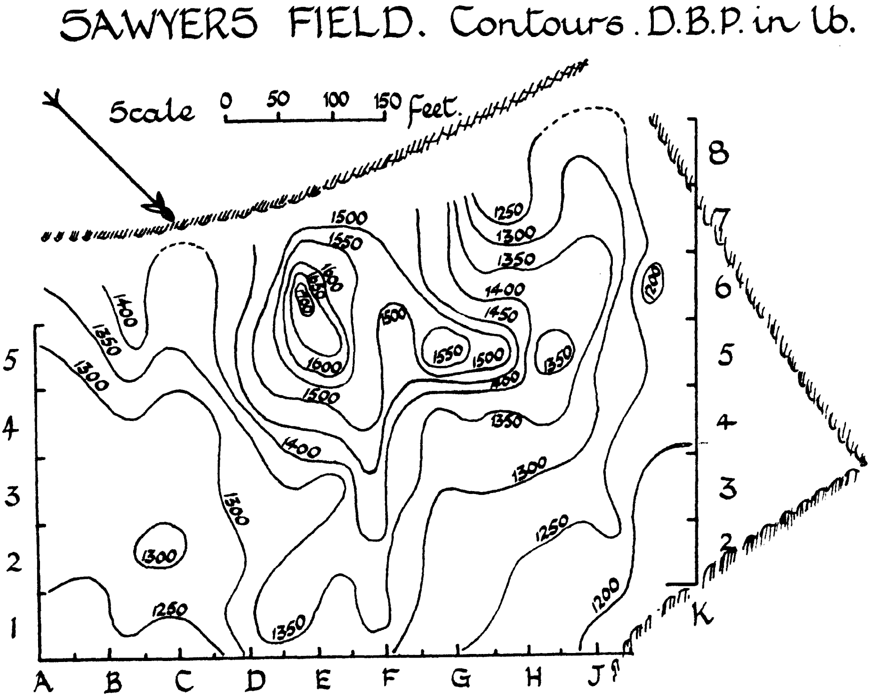

FIGURE 1.—Variation in soil resistance in a field apparently uniform to visual inspection

comparisons of this nature, which show that the accuracy is in reality much higher.

A number of other fields have been surveyed in the same manner and the existence of a wide and variable degree of soil heterogeneity has been disclosed, as will be evident from the isodyne maps referred to in the following sections.

II. PERSISTENCE OF THE VARIATIONS FROM YEAR TO YEAR

From the preceding section the danger of a visual estimate of uniformity is apparent. The question at once arises, whether these apparently erratically distributed variations of resistance are reasonably constant from year to year. In other words, would the isodyne map for one season's

ploughing be similar to that for the next season? This question has been examined in great detail, because the possibility of erratic seasonal variations would have been a highly disturbing factor in many types of field investigations. Fortunately the results of the experiments show that this possibility may be definitely excluded. Minor variations are, of course, found, especially in abnormal cases (see next section), and the general average value of the soil resistance may be different in different seasons, but the order of the actual variations from point to point remains sensibly unaltered. The isodyne map for one season is closely reproduced by the next season's results.

Results for the soil resistance on the continuous wheat plots of Broadbalk have been obtained in six successive years, and no appreciable variation in the contour maps has been disclosed. A quantitative expression to this is given by calculation for two years' records of the correlation coefficients between the detailed results from the small plots into which the area is divided for working up the dynamometer results. The value for the whole area—some 250 sub-plots—is greater than +0.8.

An even more convincing result has been obtained from the area on which the original uniformity trial was conducted (Section I). In a second experiment every variable factor except the land itself was changed: horses and a single furrow plough were used instead of a tractor and two-furrow plough, the season was spring instead of autumn, the new Rothamsted Dynamometer was used instead of the original Watson type and, most significant of all, the direction of the test furrows was at right angles to the previous season, as the land was being cross-ploughed. Yet in spite of these differences the isodyne map was almost indistinguishable from the previous one. The correlation coefficient between the two sets of values was +0.897—a very high value.

III. EFFECTS OF MANURES ON THE SOIL RESISTANCE

As already mentioned, it was anticipated in the early stages of this work that the cumulative effect of the manures on the permanent experimental areas laid down by Lawes and Gilbert would have affected the resistance offered by the soil to the passage of cultivation implements. The demonstration of the existence of soil heterogeneity prevented a direct evaluation of any manurial effects, as, with few exceptions, there was only a single plot for any given manurial treatment, and it was therefore impossible to eliminate from the data that portion ascribable to soil heterogeneity alone. The only feasible course was to obtain a complete isodyne map of the field and from the shape and direction of the isodynes in the neighborhood of the plot boundaries to make general inferences as to the effect of the plot treatments. Contour lines running across the field irrespective of the plot boundaries indicate a natural drift in the soil resistance, while those showing a sharp gradient at the region of the

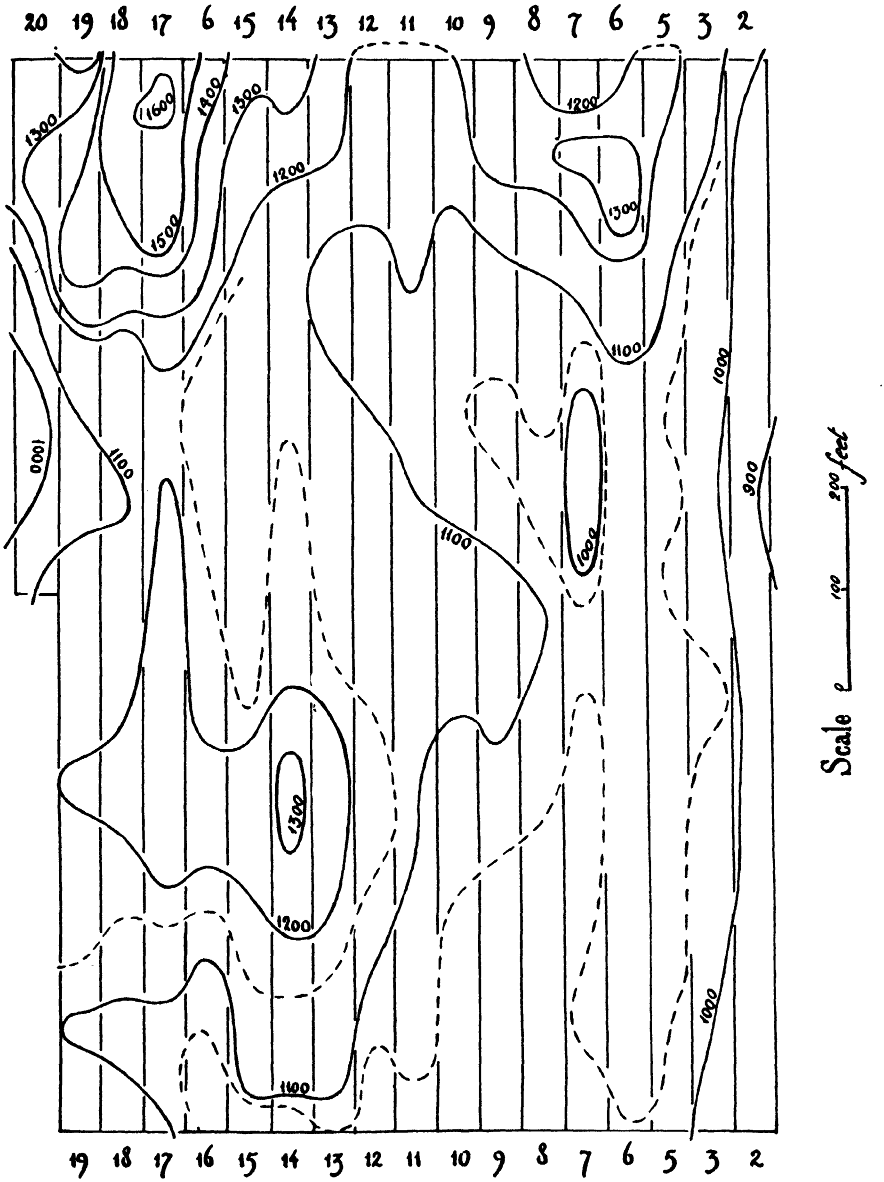

FIGURE 2.—Isodyne map for Broadbalk permanent wheat plots. Contours, soil resistance in pounds

boundaries indicate an effect referable either to plot treatment, or to some artificially induced variation. Isodyne maps, on which the position of the plot boundaries is also given, are shown in Figs. 2, 3 and 4 for Broadbalk permanent wheat, Hoos permanent barley and Barnfield permanent mangolds, respectively. It is clear from a general examination of the figures that pre-existing soil heterogeneities are predominant in determining the shape and position of the isodynes.

In the case of Broadbalk (fig. 2) all cultivation operations have been done for many years up and down the plots and not across them, and the tendency of some of the isodynes to run parallel to the long dimension of the plots can be attributed partly to this and partly to the convention followed in drawing the lines. As would be expected, the well known effect of farmyard manure in lightening the soil is confirmed by the measurements, Plot 2, which receives annually 14 tons of this manure per acre, having a much lower resistance than the other plots. There is no evidence that any of the artificial manures have produced any reduction in draft. This is particularly evident in Fig. 3, where the greater part of the field has the same resistance which the manuring has not affected.

On the other hand, dressings of chalk have a marked effect on the draft of heavy land. The isodyne map for one field is shown in Fig. 5. The chalk was applied at the rate of 15 tons per acre in 1912, and the dynamometer test was made in 1926. The lower draft on the chalked strip is most evident, even after the lapse of 14 years. Although no tests were made before 1926, except a preliminary measurement in 1919, the experience of the ploughman is that the reduced draft has been operative for many years. Chalking as a common practice in England has almost died out owing to the large increase in labor costs; the reduction in draft now demonstrated, and hitherto unappreciated, constitutes an appreciable credit item to set against the heavy initial cost of chalking. It operates to the maximum effect when the land is neither too wet or dry, that is, over the range of moisture contents within which the bulk of the cultivations are in fact carried out. Typical results are shown in the following table:

TABLE 2.—Average soil resistance

Field and date	Unchalked	Chalked	Reduction
	lb.	lb.	lb.
Sawpit. Dry stubbles: autumn	473	476	
Sawpit. Cross ploughing moist weathered furrows: spring	521	461	60
Great Knott. Moist condition: autumn	924	802	122
Great Knott. Wet condition: late autumn	1258	1181	77

Attention should be directed, not to the actual values—as these depend on the soil and on the type of plough used—but to the reduction due to chalking, as shown in the last column.

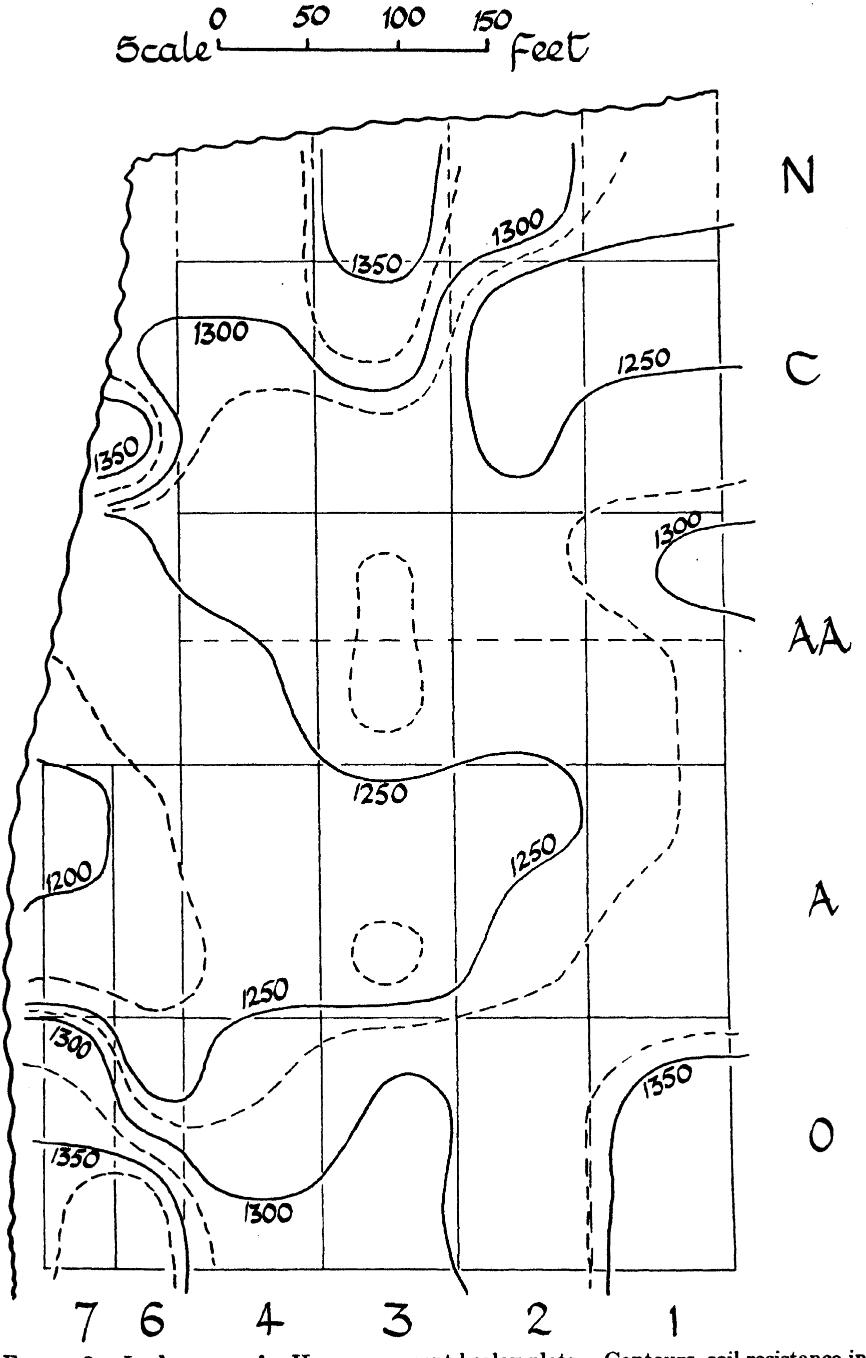

Figure 3.—Isodyne map for Hoos permanent barley plots. Contours, soil resistance in pounds

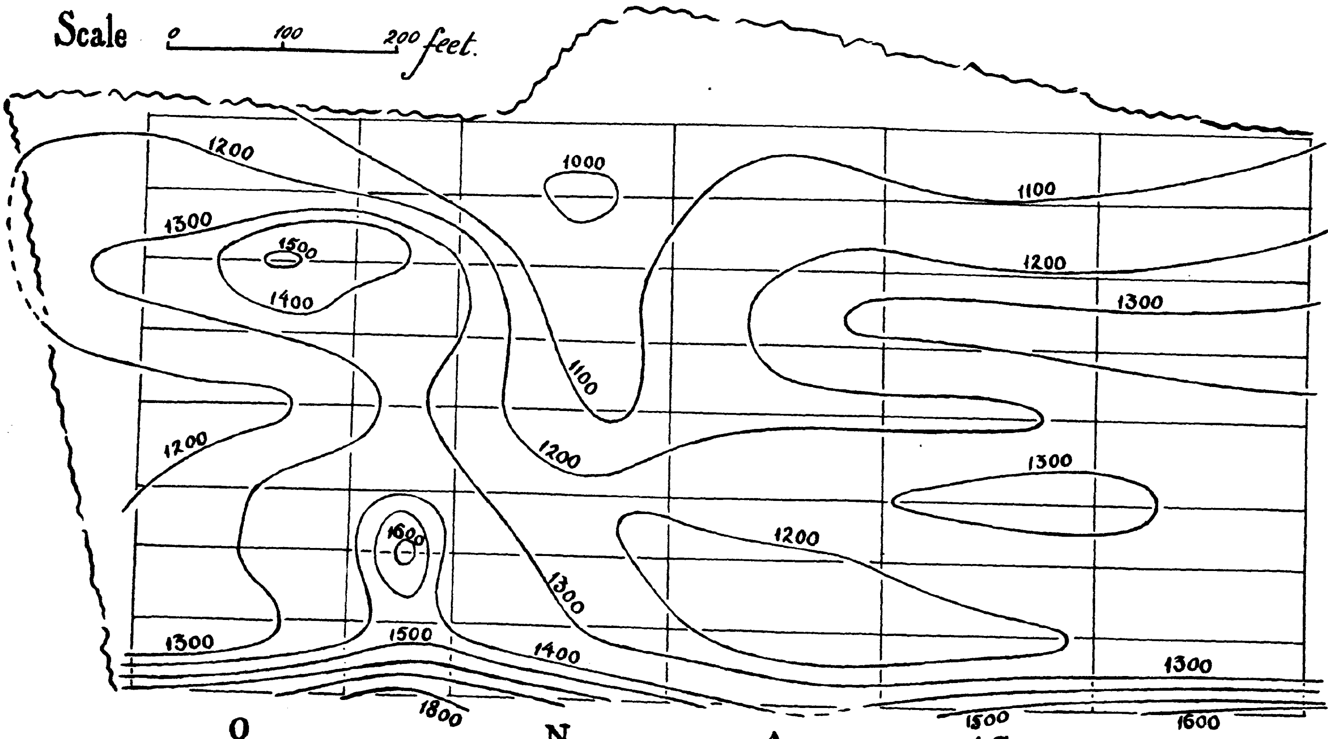

FIGURE 4.—Isodyne map for Barnfield permanent mangolds. Contours, soil resistance in pounds

There is reason to assume that small quantities of lime will produce a similar effect. This question is now under examination.

IV. RELATION OF RESISTANCE TO THE PHYSICAL PROPERTIES OF THE SOIL

The most obvious physical characteristics of a soil are its moisture content under defined conditions and its mechanical analysis. Samples of soil for moisture content are taken as a. routine determination in all

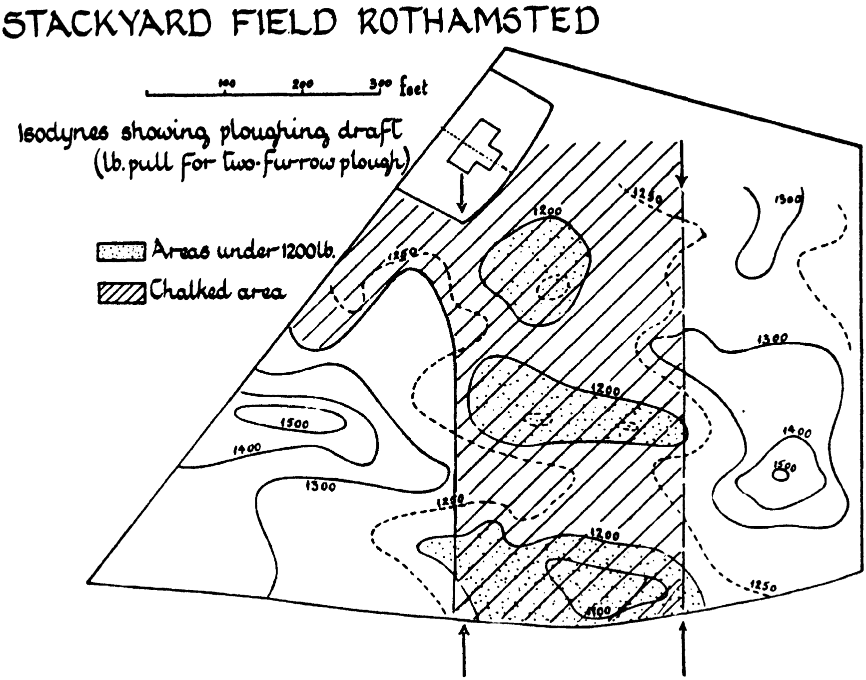

FIGURE 5.—Effect of chalking on soil resistance

dynamometer work, and during the "uniformity" trial dealt with in Section I, a comprehensive set of moisture determinations was made. The small variation occurring over the field was not related in any way to the dynamometer values. This result has been amply confirmed by numerous measurements on other fields. Excluding occasional fortuitous effects, such as shading by trees, etc., only in the case of plots receiving heavy dressings or organic manure has any relation been observed, the increase in draft on these plots being associated with higher moisture content than the rest of the field. This is no doubt an indirect association due to the direct dependence of each factor on the organic matter content.

The mechanical analysis is not related in any simple and obvious way to the soil resistance. For a given field, a broad relationship exists between the amount of clay and the soil resistance. They both increase together and the relation is approximately linear. This is no more than an expression of the "heaviness" of the soil in the sense that the farmer uses the term, and no exact relation would of course be expected. A mechanical analysis is only a summarized and approximate statement of the actual particle size distribution in a soil, and even in its summarized form it

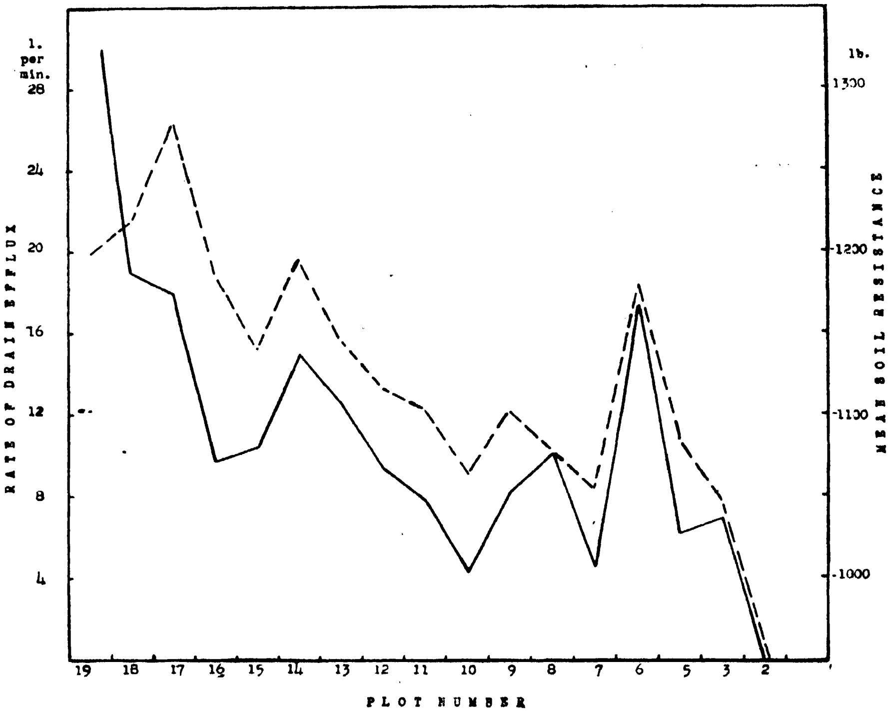

FIGURE 6.—Broadbalk Field. Comparison of ploughing drought - - - - - - and drain efflux———

consists of some five or six separate fractions. Hence it would be unlikely to find any one fraction, e.g. the clay, exclusively controlling the soil resistance.

There are certain physical properties that by their nature may be expected to show a closer relation than mechanical analysis to the field characteristics of a soil. Haines (1) has carried out an investigation of cohesion, plasticity, and the friction between soil and a metal surface, with special reference to the effect of changes in moisture content on these factors. With regard to cohesion and plasticity, although the complete curves showing the change of each factor with moisture content fall into

the same order as the dynamometer values for the soils, the relationship is not quantitative. The soil moves over the implement in a complicated manner; cohesion, plasticity, frictional forces, both between the soil and the metal surfaces of the implement and between constituent portions of the soil itself, are all concerned in this movement. Nevertheless, the dynamometer measurement of the soil resistance is the integration of these separate factors, and a further study of them offers a promising field of development. It is probable that one of them, or a simple combination, may be a suitable "single value" specification of a soil for purposes of classification. Work on this aspect is now in hand at Rothamsted.

It is interesting to note that the soil resistance is in certain conditions closely related to the measured percolation of water through the soil. On one occasion, after a heavy rainfall measurements were made of the rate of efflux of water from Broadbalk field, which is provided with pipe drains down each plot. The results are shown in Fig. 6, where the recorded rate of drainage for each plot is compared with the average soil resistance for the same plot. A close agreement is evident in the two series of values except for Plots 18 and 19, which, owing to their proximity to a hedge and ditch, are known to be affected. The agreement is the opposite from what would be expected, the heaviest plots showing the greatest rate of drainage, and it appears that the soil differences show up in retention of water rather than in simple permeability. It is probable that the least permeable subsoils, by slowing up the downward percolation, caused a greater proportion of water to be side-tracked from the top soil into the drains, which thus ran for a longer period. The measurements were made towards the end of the flow, at which time the effect just mentioned was probably predominant. This aspect of soil drainage problems is somewhat unexpected. It is being further tested in connection with some dynamometer measurements of mole drainage, in cooperation with Reading University. The dynamometer measurements themselves are of interest, as showing that the lower depths of soil show the same general heterogeneity that has been amply demonstrated for the surface soil. The isodyne map obtained during the mole drainage operation is shown in Fig. 7, in which the heterogeneity is clearly seen. Some of the changes are so abrupt as to indicate a distinct and rapid change in the character of the subsoil, e.g. from clay to gravel. It is obvious that the duration and behavior of the moles will depend largely on the type of subsoil. Normally, this information could only be obtained, even in an approximate form, by laborious digging or boring. A dynamometer survey—which can be obtained with ease during the actual mole drainage operation—enables the location and extent of any subsoil changes to be determined with accuracy.

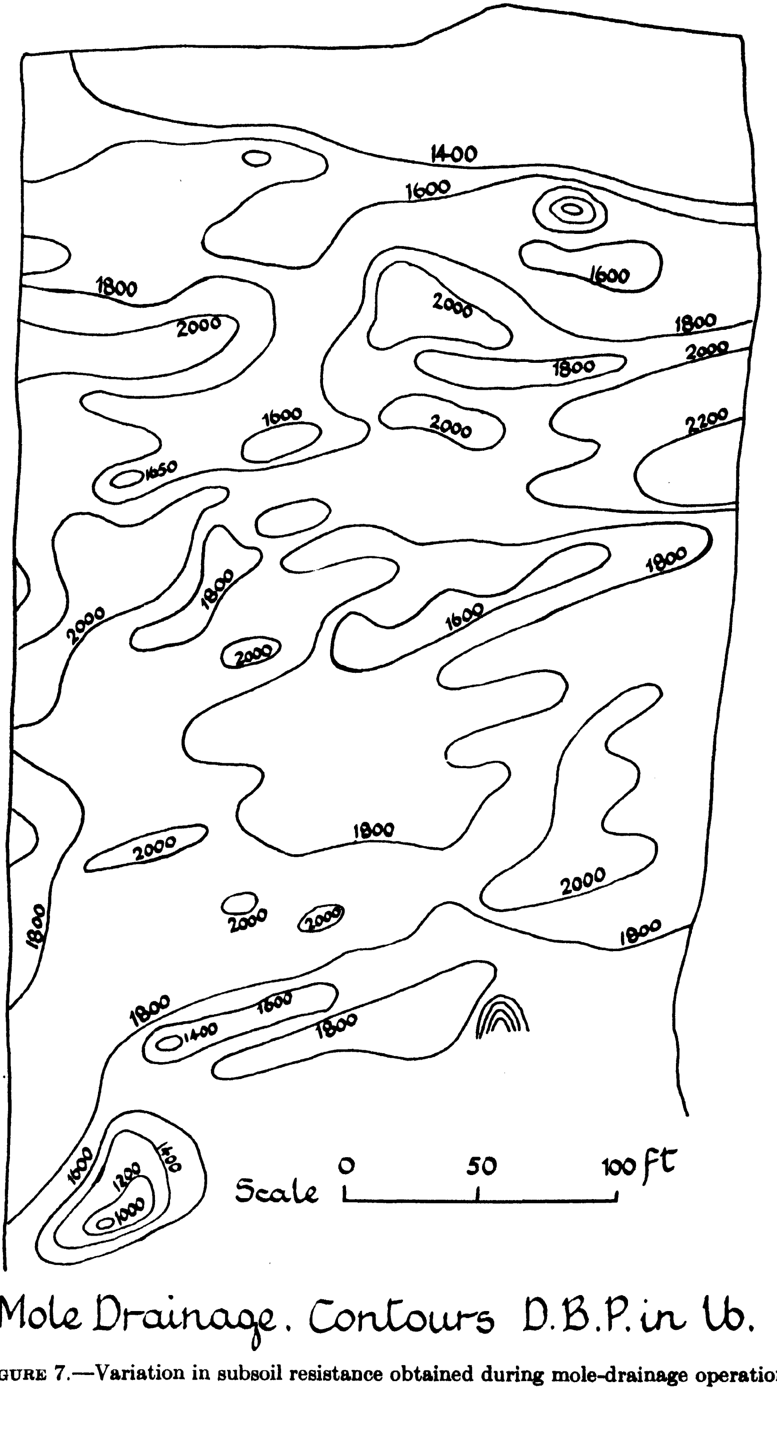

FIGURE 7.—Variation in subsoil resistance obtained during mole-drainage operation

V. RELATION BETWEEN SOIL RESISTANCE AND CROP GROWTH

Some relation between crop growth and soil resistance would be expected on general grounds, since both are related to the physical properties of the soil. In connection with the uniformity trial (Section I), careful measurements were made on 16 typical plots of the growth of the winter wheat sown on this area. The number of plants surviving the winter —i.e. the average number per unit distance along the rows—and the percentage of plants that tillered, were both highly correlated with average soil resistance of the plot. The relation was an inverse one, the heavier plots having the lowest number of plants and tillers. As growth proceeded the correlation became less and less, until at harvest time it was insignificant. This is to be attributed to the spacing effect: where the plants were less numerous they had more room for root development, and the greater yield per plant balanced the greater number of plants on the other plots.

The observations were followed up on the next crop—swedes. The data have not yet been statistically analyzed but, from general inspection, it appears that there is a relation between the average soil resistance of a plot and the yield of roots. The relationship was not inverse as was the case in the early stages of the wheat growth, but direct, the heavier plot giving the greater yield. The reason for this is not yet certain. It is possible that the process of singling, which automatically leaves single roots at regular intervals, has largely eliminated the spacing effect experienced with the wheat. On the other hand, as the singling operation was followed by a dry spell and a consequent check to growth, the plants on the heavier plot may have felt the drought less severely than those on the lighter plot, owing to the larger reserve of moisture in the heavy portions of the land.

The roots were succeeded by winter oats. Here again a preliminary visual inspection suggests that effects similar to those observed in the early stages of the growth of winter wheat are appearing. In order to have their full value, field observations of this kind have to be carried on for a number of years, as the effect of season also comes in. It is therefore proposed to carry this particular experiment through two complete rotations.

VI. BEARING OF MEASUREMENTS OF SOIL RESISTANCE ON IMPLEMENT DESIGN AND PERFORMANCE

Implement makers are accustomed to use a dynamometer for testing the draft of new models, and in competitive trials of implements. It has been assumed that an implement showing less draft than its competitors is actually easier to pull through the soil, but as this assumption implicitly

assumes that the soil is uniform throughout the whole test area it may be very wide of the truth. The usual practice is to divide the field into strips, one of which is allotted to each implement, and the average draft within the strip is used as the basis of comparison. To illustrate the dangers of this practice the figures of Table 1 can be grouped as in Table 3 to show the average value of the soil resistance for strips 21 yards wide running across the field.

TABLE 3.—Average soil resistance for strips across the whole area

Strip	A	B	C	D	E		
Average soil resistance, lb.	1,267	1,335	1,307	1,423	1,460		
	1,297	1,303	1,345	1,485	1,479		
Strip	F	G	H	J	K		
Average soil resistance, lb.	1,394	1,343	1,299	1,272	1,215		
	1,370	1,328	1,306	1,194			
Strip	1	2	3	4	5	6	7
Average soil resistance, lb.	1,276	1,279	1,297	1,343	1,428	1,417	1,337

It will be seen that there is a difference of over 10 per cent between the highest and lowest value, *when the same plough is used throughout.* Had the field been used for a competitive trial—and from a visual inspection it would have been accepted for this purpose without question—grave injustice would have been done to the implements on the heavier plots. To obtain reliable comparisons it would be necessary to make a preliminary survey of the isodyne distribution across the field and to allow for their variation in the recorded draft of the different implements or, alternatively, to replace the single strip system of tests by multiple narrow strips, allotting a series of them at regular intervals across the field to each implement.

Certain of the factors that were studied during the evolution of a reliable dynamometer technique may also be appropriately considered in this section. They were worked out for the operation of ploughing, but the principles are generally applicable.

Changes in the adjustment in the hitch or "set" of the plough have little effect on the draft, except in so far as depth of ploughing is affected.

The draft is proportional to the depth of ploughing within the normal range of surface cultivation and provided no pan, or "plough-sole" is involved, in which case the resistance greatly increases. An instance of this effect is given in Fig. 4, where Strip 1, although receiving annually large quantities of farmyard manure, shows regions of high resistance, where the tractor plough—which runs at a uniform depth—entered the clay subsoil that comes close to the surface in these areas. In horse ploughing, which is the usual practice on this field, the plough is set to ride over the clay subsoil in these areas, thus giving the lighter draft associated with organic manuring.

The effect of slope of the land on the dynamometer values is almost negligible. No measurable difference occurs for gradients less than 1 in 40. The effect of a slope in both power and horse ploughing is so obvious that this result at first sight is surprising. However, the extra effort of the tractive force is primarily that of raising its own weight against gravity. The only extra pull imposed by the plough is that required to lift its own weight, which is very small compared with the resistance offered by the soil. Thus a 300 lb. two-furrow plough, which on level ground would have a draft of 1,000 lb. due to soil resistance, would require only an extra 7 lb. pull up a slope of 1 in 40—a negligible addition.

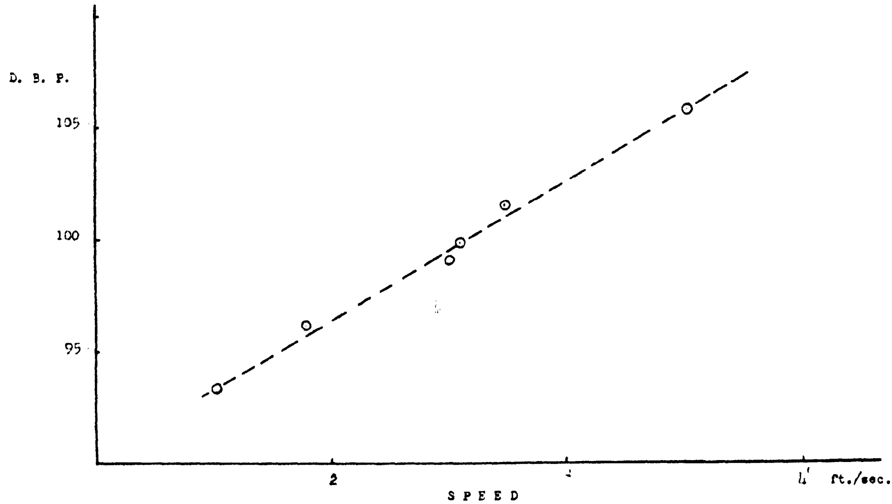

FIGURE 8.—Relationship between speed of ploughing and draw bar pull

The effect of slope shows itself primarily in the speed and not in the draft. The speed factor is perhaps the most interesting of those studied. A careful series of fully replicated experiments was made to ascertain the relation between draft and speed, with the result shown in Fig. 8, where the draft has been expressed as a percentage of that given at 2.5 feet per second.[1] When the speed is increased from 2.5 to 4 feet per second, an increase of 60 per cent, the draft increases only by 7 per cent. This slow increase of draft opens the possibility of greatly speeding up cultivation work, provided suitably designed implements and tractors can be evolved. Those now in use would have to be run much higher than their designed speeds and would rapidly depreciate. There is no fundamental difficulty in the suggestion and the command over his work that would be given to the

[1] Certain of the diagrams in this paper are taken from the Journal of Agricultural Science by permission of the Cambridge University Press.

farmer, especially at the abnormally busy seasons of autumn and spring cultivations, would be of inestimable value.

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SOME PHYSICAL PROPERTIES OF HEAVY ALKALINE SOILS UNDER IRRIGATION (IN THE SUDAN GEZIRA)

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INTRODUCTION

At the Rothamsted conference of the First Commission it was decided to invite communications to this Congress on the technique and value of laboratory methods of characterising soil-water relationships and of determining density and pore space in the field. The data given below illustrate the application of very simple experimental methods to an extreme soil type—the very heavy alkaline soil under irrigation for cotton in the Sudan Gezira. This soil has a clay content of about 57 per cent throughout the depths considered, a pH value of about 9.5 at the surface, and a salt content of about 0.1 per cent, chiefly in the form of sodium carbonate, in the first 60 cm., and anything up to 1.0 per cent of salts, chiefly sodium sulfate, below this depth. One of its most striking features is the slowness of water movement. Irrigation water may remain in the furrows for one or two days. The profile shows a hard layer which is almost impermeable to water at depths of from 70 to 100 cm. Irrigation water and cotton roots rarely penetrate this layer.

It will be shown that measurements requiring a minimum of laboratory facilities throw considerable light on the structure and agricultural behaviour of soils of this type.

DENSITY AND PORE SPACE

The density of the soil in the field was determined at the Gezira Research Farm on a series of samples taken at various depths from the side of a recently dug hole. The soil was sufficiently hard and compact to allow lumps, which had been carefully dug out by a stout spatula, to be broken or trimmed by hand to a convenient size without any appreciable deformation. The densities were determined by coating the samples with beeswax and weighing in water. The moisture content was determined on the same samples after removing the beeswax. The data given are the average of determinations made on four holes dug at different stages in the irrigation cycle. The results for the surface layer are less significant than the others on account of the wide variations in moisture content through-

out the irrigation cycle. In evaluating the pore space the true specific gravity was taken as 2.7.

Table 1 and Fig. 1 give the density of wet soil and of dry soil, i.e. the weight in grams of fresh soil and of dried soil respectively in 1 cc. of soil in its natural state in the field. There is also given the percentage composition by volume of the soil deduced from these density data and the corresponding water contents.

TABLE 1.—Density of fresh and dried soil and deduced percentage composition by volume

No.	Depth in cm.	Density wet	Density dry	Percentage composition by volume		
				Soil	Water	Air
1	0–15	1.64	1.32	.49	.32	.20
2	15–30	1.66	1.26	.47	.41	.13
3	30–45	1.71	1.31	.49	.39	.12
4	45–60	1.75	1.37	.51	.37	.11
5	60–75	1.77	1.44	.53	.33	.14
6	75–90	1.81	1.49	.55	.32	.13
7	90–105	1.77	1.44	.53	.33	.14
8	105–120	1.75	1.41	.52	.33	.14

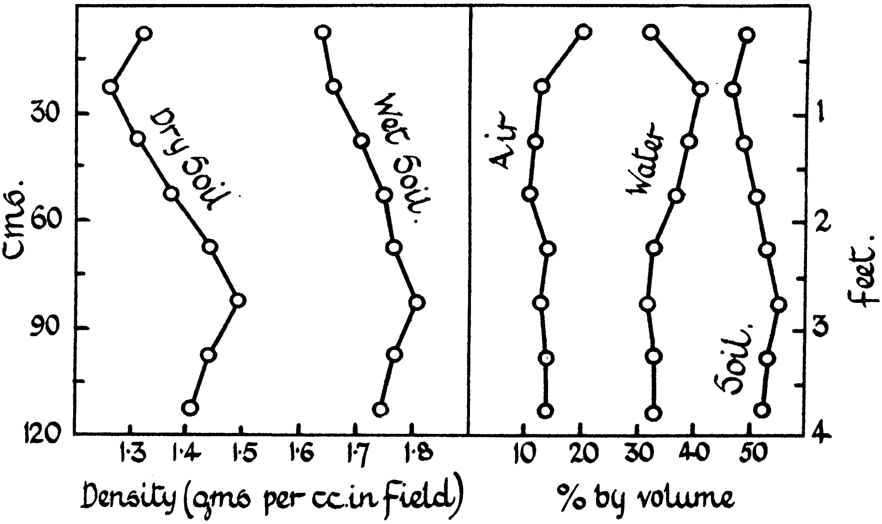

FIGURE 1.—Density of fresh and dried soil and deduced percentage composition by volume

The densities are high throughout and the air contents (11 to 14 per cent by volume) so low as to suggest defective soil aeration. There is a steady increase with depth of the density, or closeness of packing of the soil

particles, up to a maximum value at about 80 cm. This corresponds with the observed hard layer in the soil profile and with the depth at which there is no appreciable change in water content throughout the irrigation cycles. The closeness of packing is clearly one of the factors responsible for the slow water movement, but it is not the only factor since laboratory measurements on the percolation of water into loosely and uniformly packed soil samples also show a low permeability at this depth.

RATE OF PENETRATION OF WATER

The rate of downward movement of water under a constant 5 cm. head of water was determined for a series of soil samples from successive 6 inch

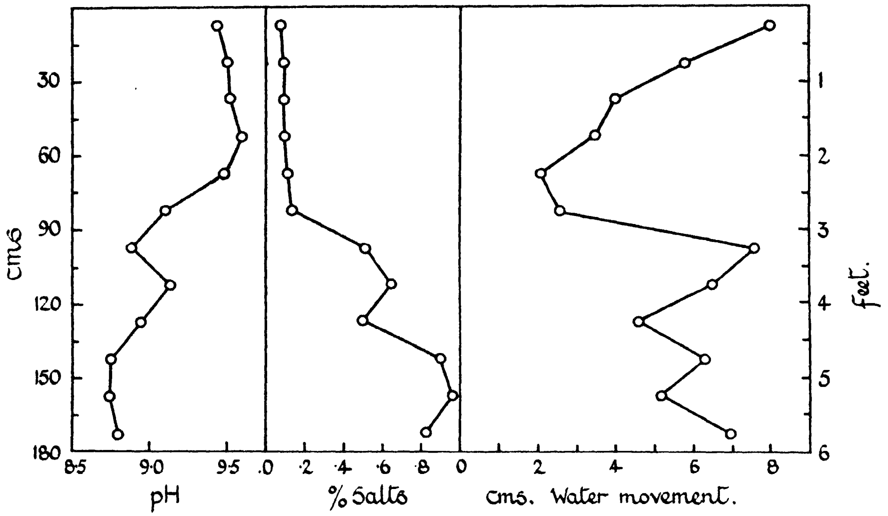

FIGURE 2.—Downward movement of water under a constant 5 cm. head of water

layers at the Gezira Research Farm. Air-dried samples, which had passed a 1 mm. sieve, were packed as uniformly as possible into wide glass tubes, closed at the bottom by gauze and filter paper. Readings of the depth to which the water had penetrated were taken at suitable times. To eliminate any irregularities during the relatively rapid movement in the first few minutes after adding the water, the amount of downward movement in the interval between 10 and 1000 minutes was taken as a measure of the rate of penetration of water. Typical results are given in Table 2 and Fig. 2, together with the salt contents of the samples and the pH values of other samples taken from an adjacent hole.[1]

Even under uniform conditions of sieving and packing and with pore spaces much greater than those in the field, there is a marked falling off in

[1] The salt contents and pH values were kindly provided by Drs. Greene and Joseph respectively.

the rate of water movement in soil from successive depths down to about 80 cm. The minimum value is only one quarter of that for the surface soil. At greater depths the rate of water movement is greatly increased by the flocculating action of the large amounts of sodium sulfate present.

TABLE 2.—Downward movement of water under a constant 5 cm. head of water

Depth in cm.	0–15	–30	–45	–60	–75	–90	–105	–120	–135	–150	–165	–180
Water movement in cm.	8.0	5.8	4.0	3.5	2.1	2.6	7.6	6.5	4.6	6.3	5.2	7.0
Salts %	0.08	0.09	0.09	0.10	0.12	0.14	0.52	0.64	0.50	0.90	0.97	0.83
pH value (of similar samples)	9.44	9.51	9.52	9.59	9.49	9.10	8.89	9.14	8.95	8.76	8.75	8.81

RATE OF CAPILLARY RISE

It is a common field observation that irrigation water is taken up more rapidly by soils giving high yields of cotton than it is by those giving low yields. Similar differences are obtained in simple laboratory measurements on the rate of capillary rise in such soils. Air-dry soil samples passing a 1 mm. sieve were uniformly packed into narrow glass tubes with the lower ends loosely closed by cotton wool and standing vertically in a tray. The rate of capillary rise was measured by the amount of water movement in cm. in the interval between 10 and 1000 minutes after pouring water into the tray. Two typical series of comparisons are given in Tables 3 and 4.

TABLE 3.—Rate of capillary rise in successive layers from adjacent good and bad soils, which had given yields of 340 and 140 lb. of ginned cotton in the preceding year

Depth in cm.	0–15	15–30	30–45	45–60	60–75	75–90	90–105	105–120
Capillary rise								
Good soil	11.9	5.5	3.5	4.9	3.3	2.3	5.1	2.7
Bad soil	7.6	3.3	3.0	2.7	4.4	5.3	4.0	3.9
Per cent salts								
Good soil	0.05	0.08	0.08	0.08	0.09	0.13	0.41	0.38
Bad soil	0.07	0.11	0.12	0.26	0.49	0.42	0.39	0.41

There is a wide difference between the good and the bad soil and an intimate relationship between water movement and salt content. The good

TABLE 4.—Comparison of the mean values of a series of seven good and six bad soils, not widely separated [a]

Depth in cm.	0–15	15–30	30–45	45–60	Mean 0–60
Capillary rise					
Good soils	9.2	8.2	5.6	4.4	6.8
Bad soils	5.3	3.8	3.8	3.4	4.1

[a] Mean yields in preceding year 350 and 150 lb. of ginned cotton per acre. Mean salt contents from 0 to 30 cm., 0.066 per cent and 0.084 per cent.

soil gives the more rapid movement in the first 60 cm. in accordance with its lower content of deflocculating salts (sodium carbonate); below this depth the good soil gives the slower movement owing to its lower content of flocculating salts (sodium sulfate). The rate of movement falls off fairly steadily from the surface to 90 cm. in the good soils and to 60 cm. in the bad soils. These depths are the ones at which an appreciable increase in salt content first occurs and are 15 cm. above the first maximum value in salt content.

The good soils give the more rapid water movement. The differences are more marked in the surface than at 45 to 60 cm. The rate of water movement falls off steadily with the depth.

There is a general parallelism between high yield, rapid water movement and low salt content. Simple measurements of the rate of capillary rise should provide a useful supplement to the salt determinations in the rapid characterisation of soils of this type. For although the salt content is probably the more fundamental factor, the rate of water movement is undoubtedly a factor of direct practical importance for a crop grown under conditions of acute water strain.

METHODS FOR PHYSICAL EXAMINATION OF SOILS

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INTRODUCTION

It has always been desired by soil workers to obtain some standard for comparing different soils. Many measurements of soil material have been made in different ways in an effort to determine a standard, but without success in finding anything that would furnish information sufficient to differentiate soils or to indicate their productivity. A soil is too complicated to be judged simply by its constituents or by any single property or group of properties. With the beginning of the study of soils by horizons it became recognized that the properties of these horizons should be determined in order to obtain a correct knowledge of the soil as a whole.

A difficulty was encountered of devising or utilizing methods for determining these properties. After considerable experimentation the Bureau of Soils has been using for the last few years certain methods in examining soil samples whose physical characteristics are to be determined.

When samples of soil material generally by horizons have been collected for the purpose of determining their physical characteristics, they are examined to determine mechanical composition, amount of colloid, moisture equivalent, percolation, real specific gravity, apparent specific gravity, pore space, penetration, and plastic range. Maximum water holding capacity was determined on a number of soils but was found to furnish information no more valuable than that obtained by determining the moisture equivalent.

Similar work at the Michigan Experiment Station by Wheeting, (4) and by McCool, Veatch and Spurway, (1) has been described in which chemical and physical characteristics of the soil materials were measured.

COLLECTION OF SAMPLES

The samples were collected from the different soil horizons and at times several samples were taken from the same horizon. The samples were obtained in two different ways, (a) by digging out a block about 1 foot cube from the side of a cut or, if no cut were available, from the side of a pit dug for the purpose, and (b) by pressing the open end of a heavy tin can horizontally into the face of a cut and cutting off the soil material column even with the top of the can. In the case of the blocks obtained under (a)

they were packed as securely as possible each in a wooden box and shipped to the laboratory. Where the samples were obtained in cans they were placed in a wooden box holding 8 such cans and shipped to the laboratory for examination. With the use of either method the samples were received at the laboratory generally in the condition obtaining in the field. In certain soils with insufficient amount of clay material to give them coherence there was shattering or compacting of the material in shipment. Obviously such samples could not be used for certain determinations intended to show the field conditions of the soil, but they could be used for such tests as amount of colloid, and moisture equivalent, as will be seen under the description of these methods. The cans used were made of rather stiff tin plate, were 4¼ inches in diameter and 2½ inches deep with a lid closely fitting over the top edge. After closing, a piece of rubber adhesive tape was fastened around the can at the junction of the lid with the can wall, so that the moisture of the sample was retained. The block samples became air-dried generally before reaching the laboratory. Where cans were used for the collection of samples, two can samples were taken at the same location. The contents of one can was used for such tests as do not require preserving the sample in its field conditions, the other was used for penetration measurements, percolation and moisture equivalent.

MOISTURE CONTENT OF SOILS

The moisture content was determined on the sample as received in the sealed containers whenever it seemed desirable. The determination was made by drying in an electric oven at 105° C. and the percentage of moisture on the dry weight of the sample estimated from the loss in weight.

MOISTURE EQUIVALENT DETERMINATIONS

Moisture equivalent determinations were carried out in the usual apparatus designed for that purpose. In order to determine if the moisture equivalent of soils in the field condition is different from that of the same soil crushed and screened to pass a 2 mm. sieve, a number of determinations were made on duplicate samples. The crushed sample was moistened and whirled in the centrifuge in the ordinary manner. For the duplicate determinations, in order to preserve the structure, blocks of soil were broken out and worked down by breaking off particles from the sides to a size that would just fit into the ordinary moisture equivalent soil box. Such blocks weighed 30 g. in all cases. The samples were then moistened and run in the centrifuge in the usual way. Results of these duplicate measurements are shown in Table 1.

The results obtained showed a fairly close agreement between the two kinds of samples. In most cases the lump soil gave a slightly lower value than the soil in the crushed condition. Such slight difference is indicated

that it does not seem necessary to change the ordinary method of determining moisture equivalent on the crushed sample of soil.

TABLE 1.—Moisture equivalents of crushed soil and of soil in field condition

Soil sample	Per cent moisture	
	Crushed sample	Block sample
Leonardtown No. 1	22.9	19.7
Do No. 2	24.1	21.3
Do "B"	30.5	29.9
33140	34.7	29.2
33141	45.4	41.4
33142	32.0	31.5
32493	13.3	10.4
32494	28.0	26.9
33420	7.9	7.1
33421	7.9	6.8
33422	17.4	16.4
33423	19.3	16.6
33425	10.5	8.9
33426	23.5	23.7
33427	22.7	22.9
33412	6.9	7.5
33415	11.3	10.0
33416	11.2	10.8
33417	13.3	12.8
33180	22.9	23.1
33182	14.4	13.9
33184	23.7	23.9
33188	25.0	24.6

MAXIMUM WATER HOLDING CAPACITY OF SOILS

As a matter of comparison with the moisture equivalent values, the amount of water retained in soils under the influence of gravity was determined. Metal boxes with perforated bottoms containing the soil samples were set in water to completely saturate the soils. The boxes were then removed from the water and allowed to drain for 12 hours under a bell jar in an atmosphere saturated with water vapor. The boxes were quickly weighed and the amount of water present in the soil determined. These determinations were carried out on both the crushed soil and on blocks of soil in the field condition. In some cases of sandy soils there was not enough coherence between the soil grains to permit of obtaining the soil blocks. In Table 2 are shown results of measurements on several soils.

These results show that the sample in the block form retains less water in every instance than the crushed sample, which would indicate that in

the block form the soil particles are aggregated into larger units and the interstitial spaces are much larger than in the crushed material.

TABLE 2.—Maximum water holding capacity of soils

Soil sample	Per cent of moisture after draining 12 hours	
	Block sample	Crushed sample
Leonardtown No. 1	33.1	45.0
Leonardtown No. 2	36.1	47.9
Leonardtown "B"		59.1
32493	24.1	36.6
32494		59.7
32206	32.8	45.6
32207	32.0	52.7
32208	44.9	57.1
32209	33.8	36.8

PERCOLATION OF WATER

As in the other tests described, percolation was determined on the crushed material and on the block material. Determinations on the crushed material were made with a column of soil 6.3 cm. or 2½ inches high in a glass cylinder 3.7 cm. or 1½ inches in diameter. The cubical dimensions of the soil was 73 cc. or 2.49 cubic inches. The soil was compacted by tapping the bottom of the tube on a table top until no further settling was observed. The lower end of the cylinder was closed by filter paper supported by wire gauze. The percolate was caught in a graduated cylinder and measured at certain time intervals, depending on the rate of percolation. A 2.8 cm. or 1⅛ inch head of water was maintained by an automatic flow from a large bottle reservoir. For a determination of percolation on a block sample, a soil cylinder 2 inches in diameter and 3 inches long was cut from the larger block. A metal tube with toothed lower edge is convenient for cutting out such a cylinder. The upper end of the soil cylinder was placed just inside the lower end of a slightly larger glass tube and cotton waste packed between the soil and the glass. The glass tube was necessary to furnish a method of introducing water under a definite head to the end of the soil column. A short section of the glass tube and the entire soil column were wrapped spirally with a 2 inch strip of rubber dam and the outside coated with paraffin. The lower end of the soil column rested on wire gauze placed over the top of a funnel and a filter paper laid on it. This device was employed as it was impossible to fit a soil column perfectly into any rigid walled vessel. With this arrangement all percolating water was forced to find its way through the soil column and could not follow any channels along the wall.

When the sample collected was in a metal can as previously described, the bottom of the can was cut off without disturbing the soil contents. A brass ring was attached to the top of the can, and the joint covered by a wide rubber band, to furnish a place for water to cover the soil surface. Melted paraffin was poured around the edge of the soil next to the can wall so that no channels were left open along the outside of the soil column. The whole sample was used for the percolation test. The results were expressed as average cubic centimeters per minute, average cubic centimeters per gram of soil and average cubic centermeter per cubic centimeter of soil. The last method of expressing the percolation is most desirable for comparison between different soils.

REAL AND APPARENT SPECIFIC GRAVITY

The real specific gravity was determined in the usual pyknometer method for dry powders, using water as the liquid of comparison. This value is fairly constant for most soils and averages close to 2.65.

The apparent specific gravity was determined by the method first described by Trnka (3) of dipping a small weighed block of dry soil in melted paraffin until the soil is coated over the outside, reweighed in air and then in water. The weight of paraffin taken up is the difference between the two weights in air. The true weight of paraffin in water is determined from its weight in air and its specific gravity. The true weight of paraffin in water is deducted from the weight of soil and paraffin in water, in order to get the weight of soil in water. The apparent specific gravity is then found by dividing the weight of the lump of soil in air by its weight in water.

By attaching a very thin copper wire to the soil lump it may be easily dipped in paraffin. The thin coating is allowed to cool and harden and the lump is dipped a second and sometimes a third time to insure closing all the openings on the surface of the soil to prevent entry of water when the lump is later immersed in that liquid.

With samples of soil material having little coherence an effort was made to introduce hot paraffin into the pores and thus preserve the structure of the material. Determinatons of apparent specific gravity carried out with soils so treated showed them to be much more dense than the character of the soil would indicate. On further investigation it was found that this method could not be used because the paraffin contracted on cooling when the lump of soil is saturated with it, the whole mass is considerably contracted. The method adopted with a soil of slightly coherent nature is to send into the laboratory the sample collected in the metal can as already described and by obtaining the weight of soil and the volume of the can to determine the apparent specific gravity. This method may be used on any sample of soil if care is taken in collecting the

sample to have the container completely full. Comparative results by the paraffin dip method and the can volume method show only small differences.

POROSITY OF SOILS

The porosity of soil materials was determined by a simple arithmetic calculation involving the values found for the true specific gravity and the apparent specific gravity. If *a* represents the apparent specific gravity and *s* the true specific gravity, then the pore volume in a unit volume of soil is represented by the formula $P = 1 - \frac{a}{s} = \frac{s-a}{s}$, and by multiplying the quotient by 100 the porosity in per cent is obtained.

COLLOIDS

The amount of colloids present in soil material is determined by the water adsorption method as described by W. O. Robinson (2). The soil material is air-dried and the amount of water adsorbed when it is exposed to a saturated atmosphere over 2 per cent sulfuric acid solution by volume (3.3 per cent by weight) is determined under temperature controlled conditions. For the determination about 2 g. of air-dry soil in a finely crushed condition is weighed out in a shallow weighing bottle about 30 mm. wide. The uncovered weighing bottle is placed in a vacuum dessicator with the 2 per cent sulfuric acid in the bottom and evacuated until the acid is just about to boil. The dessicator stop-cock is closed and the dessicator placed in an air bath at a temperature of 250° C. The temperature is controlled to within 0.02°. In most cases adsorption of water vapor by the soil will be complete in 48 hours but it is advisable to allow the dessicator to remain in the bath for 5 days. When the dessicator is removed, air is allowed to enter slowly, then the weighing bottle is quickly covered and after cooling weighed to determine the amount of adsorption. The soil sample is then dried at 110° C. and the weight of the dried sample determined. The difference between this weight and that of the soil with the adsorbed water gives the total water adsorption. Since the average adsorption of different colloids over 2 per cent sulfuric acid is about 0.3 g. of water per gram of colloid, the amount of adsorption of 1 g. of soil divided by the 0.3, the average colloid adsorption, and multiplying by 100 gives the percentage of colloid present.

PENETRATION

The penetration value of the soil is determined on the block or can sample of material by the use of a penetrometer of the New York Testing Laboratory type. The needle used is the same as used in testing bituminous materials. Blocks of soil were tested for penetration in the moist condition as received from the field and with varying moisture content as the samples dried out. An average was made of five or six readings at

any given moisture content of measurements taken over an area about 4 inches in diameter, and this average taken as the penetration value. Measurements were made on the dry soil at times when received in such condition and then the surface of the block was moistened with atomized water spray and the soil allowed to stand in a saturated water vapor atmosphere in a closed dessicator for 24 hours in order to insure uniform distribution of water throughout the soil mass. Determinations were then made of penetration value and of moisture content and the same procedure followed for several moisture contents. It was found more satisfactory to make measurements on a naturally moist soil and as it dried out. The

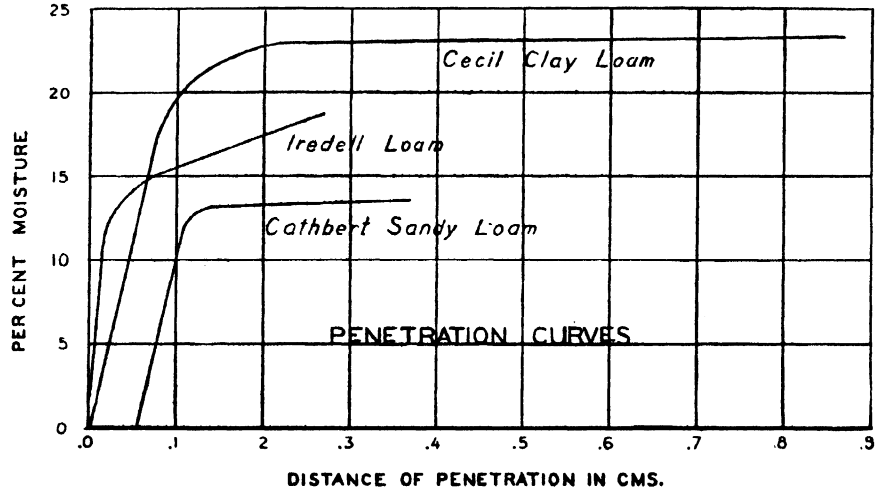

FIGURE 1.—Penetration curves, showing relation of moisture and penetration

penetration is measured in terms of millimeters for 10 seconds with a weight of 50 or 200 g. applied. From a series of values at 4 or 5 moisture contents a curve may be constructed for the soil using per cent moisture and millimeters penetration as coordinates. The curves for 3 soils are shown in Fig. 1.

With some soils of an incoherent nature the resistance is so small that a needle cannot be used. With such soils instead of a needle a portion of razor blade welded to a needle shaft is used as the penetrating instrument. The length of the forward edge of the blade is 1 cm. The results obtained with the blade may be used to construct curves in the same manner as where the point is used, and the same character of curve is obtained.

PLASTIC RANGE

The plastic range (5) of soil is determined by the Atterberg method of determining the moisture content at the lower plastic limit and that at the lower liquid limit. Between these two moisture contents is the plastic

TABLE 3.—Physical properties of soils under field conditions. Samples from Lee County, Georgia

Property	Greenville loamy sand [a]				Greenville sandy loam [a]			
	33412 [b]	33413	33414	33415	33416	33417	33418	33419
Sample Depth	3-6 in.	42 in.	48 in.	7 ft.	0-3 in.	7-10 in.	36 in.	8 ft.
Horizon	A_1	A_2	B	C	A_1	A_2	B	C
Apparent Sp. Gr.								
Paraffine method	1.63	1.72	1.78	1.72	1.66	1.76	1.79	1.89
Real Sp. Gr.	2.65	2.65	2.65	2.66	2.63	2.67	2.69	2.74
Pore space per cent	38.5	35.1	32.8	35.3	36.9	34.3	33.5	31.0
Percolation								
cc./min.	159.8	107.3	157.3	71.0	99.9	70.6	13.3	2.2
cc./g. soil	35.6	22.3	33.7	14.4	20.4	15.1	2.7	0.4
cc./cc. soil	55.3	37.2	54.4	24.6	34.6	24.4	4.6	0.8
Equivalent								
Fine	6.9	8.2	9.4	11.3	11.2	13.3	16.8	21.8
Block	7.5	7.3	8.2	10.0	10.8	12.8	15.3	19.7
Plasticity								
Lower plasticity limit			14.0	15.5	15.1	12.7	18.4	19.4
Lower liquid limit	14.9	15.9	19.6	24.4	17.6	20.3	26.4	32.8
Plastic range			5.6	8.9	2.5	7.6	8.0	13.4

[a] Loamy sand—less than 20 per cent clay; 35 per cent or more of sand over .25 mm. in dia.
Sandy loam—less than 20 per cent clay; 20 to 50 per cent silt + clay; 25 per cent or more of sand over .25 mm. in dia.
[b] Sample Number.

range of the material. The lower plastic limit is determined by mixing a sample of soil with water until it becomes plastic and then rolling it under the palm of the hand on a piece of wrapping or other heavy paper into a roll about ⅛ inch in diameter. This soil is reworked until crumbling takes place when an attempt is made to form a roll. The moisture content at this point is taken as the lower plastic limit. For the lower liquid limit a small quantity of soil is placed in a dish and made pasty with water, using a spatula to give thorough mixing. It is then smoothed into a layer about ⅜ inch thick at the center of the dish. With a spatula the mass is divided with a V-shaped trough between the halves and the two portions pushed apart about ⅛ inch at the bottom. One side of the dish and then the other is tapped 10 times, each, in succession against the hand, giving the blows the same intensity. When the two portions of wet soil just flow together under this treatment, the lower liquid limit has been reached. The moisture content at this point and at the lower plastic limit is determined and calculated in per cent on the dry weight of the soil. The difference between these two values is the plastic range. While the technique of handling soils to determine the plastic range must be developed by experience, it has been found that an operator can duplicate results very readily.

EXAMPLE OF MEASUREMENTS

In Table 3 is shown some of the measurements on 2 soils, Greenville loamy sand and Greenville sandy loam, similar in many characteristics.

The horizons of the 2 soils occur at almost the same depths. The pore space indicates a more open surface layer in the loamy sand and maximum density is reached at 48 inches in the loamy sand and at 8 feet in the sandy loam. Percolation measurements show the sandy loam decidedly less pervious than the loamy sand while the moisture equivalent shows the sandy loam more retentive of moisture than the loamy sand.

SUMMARY

The properties measured are those that can be applied to soils through practically the whole range of soil classes, from those of a sandy character to those composed almost entirely of clay material. Each of these values indicates certain peculiar characteristics of the soil and there does not appear to be any close correlation between the different properties. The measurement of them, however, indicates similarities and differences between soils. Penetration curves indicate, for instance, the moisture range over which a soil is most easily handled in tillage. Percolation measurements indicate the power of a soil mass to absorb rainfall, and also the relative permeability of the soil horizons. The relation of moisture equivalent to wilting coefficient has been long established. The plastic range is a property not sufficiently understood to draw any definite conclusion from at present. Soils of wide plastic range in general are high in clay and a narrow plastic range is associated with sandy soils. But whether the significance of the physical measurement can be explained or not, the determination of this value affords a comparative basis for soils.

Pore space determination perhaps furnishes information of as great value as any single property. A zone of concentration is indicated by low percentage of pore space, but percolation or drainage cannot be estimated from the pore space found, because the rate at which water will pass through a soil is dependent on the size of the interstitial spaces as well as the amount. From the standpoint of management and of moisture supply the penetration curve and moisture equivalent are of most practical value.

While the data collected have been insufficient so far to indicate how the different properties are related, measurements of such properties must be made to arrive at the differences between different soils.

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THE EFFECTS OF ORGANIC MATTER ON THE TILLAGE OF A CLAY SOIL

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INTRODUCTION

This discussion is concerned with the heavy black clay soil of the North Dakota Agricultural Experiment Station rotation plots. This soil answers the description given by the Bureau of Soils for Fargo Clay. It is typical of the flat areas of heavy clay soil in that portion of the Red River Valley which once comprised the basin of Glacial Lake Agassiz. Gumbo is the popular name for this type of soil.

In the two plots under discussion, no important differences in soil texture have been observed to date. If differences in the behavior of the soils of these plots be noted, they should be attributed to causes independent of soil texture.

TABLE 1.—Dynamometer tests

Rotation Corn-Barley-Clover-Wheat			Rotation Corn-Barley-Timothy or Millet-Wheat		
October 15, 1926					
Field	6B	6D	Field	5B	5D
Treatment	No manure	Manure	Treatment	No manure	Manure
Crop	Wheat	Wheat	Crop	Wheat	Wheat
Yield	33.1	33.2	Yield	15.6	19.0
Number trials	12	11	Number trials	11	10
Draw-bar pull	962 lb.	881 lb.	Draw-bar pull	1027 lb.	1040 lb.
Total width	22 ft.	21 ft.	Total width	19 ft.	20.5 ft.
Average depth	6.27 in.	6.11 in.	Average depth	6.45 in.	6.175 in.
D. B. P. per sq. in.	6.98 lb.	6.30 lb.	D. B. P. per sq. in.	7.68 lb.	6.85 lb.
April 23, 1926					
Field	6A		Field	5A	
Volume weight	1.058		Volume weight	1.110	
Pore space	57.3		Pore space	55.2	
Nitrate nitrogen	18.4 p.p.m.		Nitrate nitrogen	10.5 p.p.m.	

On September 29, 1922, the writer examined 40 plots shortly after plowing. Marked differences were noted in the tilth produced. The poorest tilth of the 40 plots was found on a plot cropped to corn, barley, timothy, and wheat. When timothy fails, millet is substituted. The best tilth of the 40 plots was on a plot cropped to a rotation of corn, barley, wheat, and clover. This plot has received some manure; the amount is of no conse-

quence in this discussion. During the growing season of 1922, it supported a growth of sweet clover.

Originally, the plots were the same—a prairie sod first plowed in 1882. They were cropped to wheat continuously for about 10 years.

In 1892, a definite crop rotation experiment was laid out and revised in 1907 and once at a later date.

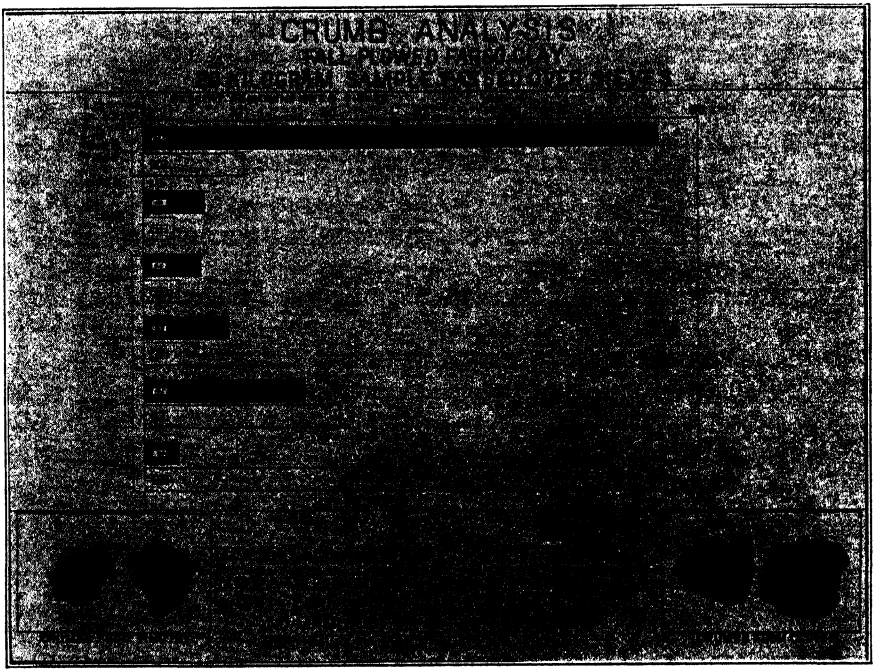

FIGURE 1.—Crumb analysis and enlarged crumbs from Timothy and Clover rotation

This history reveals the fact that the soil has received different treatment for only about 10 to 15 years, which is a short interval in the history of a soil.

The essential difference between these two plots has been the character of the sod forming crop and the added manure. To speak in broader terms, one plot received more organic matter than the other. For sake of reference, the plot of poorest tilth or seed bed will be called the timothy plot and the best the clover plot.

RECORD OF FIELD CONDITIONS

In order to obtain a record of the field conditions, a bulk sample was taken from 10 spots in each plot. After thorough mixing, a 20 kg. subsample of each was passed over screens for a "crumb" analysis.

The difference in the plots was so great that 53.7 per cent of the timothy sample remained on a 1¾ in. screen, compared with 3.7 per cent in the case of the clover plot.

The samples then passed screens with openings of ½, ¼, ⅛, and $^1/_{16}$ in. Only 10.8 per cent of the soil from the timothy plot passed through a $^1/_{16}$ in. screen compared with 55.7 per cent in case of the clover plot. Three hundred gram subsamples of fine earth which passed screens 40, 60, 80 and 100 meshes to the inch. Graphs show the percentages by weight of these separates. At a glance we see the clover plot was in better tilth. The crumbs of the clover plot broke so easily that the analysis scarcely indicates the full degree of crumbiness. The clods of the timothy plot broke so little that no real inaccuracies developed.

Photographs were taken of the various sized soil crumbs. (fig. 1.) All crumbs of the timothy plot bore sharp edges and were inclined to break in two directions or when deviating from this, break with a conchoidal fracture. These crumbs appear more like minerals or other substances of nearly constant chemical composition throughout their mass.

In the case of the clover plot the crumbs were rounded and irregular, far more granular in structure than the timothy plot.

This organic matter has produced granulation to a greater extent in one plot than the other. Inasmuch as all clay soils contain more or less colloidal matter, the flocculation has been more completely accomplished in one than in the other. How is this done? First, let us postulate that inorganic colloids are mixed with organic colloids. Upon drying differential stresses are introduced which promote granulation.

Second, the presence of organic matter introduces decomposing material of definite structure. As this organic matter decays, physical weaknesses may develop which result in lines of cleavage in the soil colloids and produce granulation about foci by purely physical means.

A third and less likely postulation, the differences in the sod forming plants in the rotations under discussion may introduce into the surface soil either ions of different elements or in such different proportions, the soil solution of the clover plot is more effective in producing the degree of flocculation necessary for good tilth.

THE ADSORPTION OF WATER VAPOR BY SOILS AND SOIL COLLOIDS

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INTRODUCTION

In a previous publication (2) of this bureau it has been shown that the ratio of the quantity of water vapor adsorbed by a sample of soil material to the quantity of water vapor adsorbed by a sample of colloid extracted from the soil material, indicates the amount of colloid in the soil material. It has further been shown by Robinson (4) that under specified conditions all soil colloids adsorb about the same quantity of water vapor which he found on the average to be 0.298 g. of water per gram of colloid. The use of this factor is very convenient in estimating the quantity of colloid in soil material since it does not involve extracting the colloid which is a tedious operation. Although this method does not give highly accurate results, it is very useful for certain investigations. Moreover it may give just as accurate results as the ratio method if the results by this latter method are not corrected for alteration in the adsorptive capacity of the colloid by extraction. Since the factor method appears to give a fairly accurate estimation of the colloidal material in most soils, the influence of varying conditions on this determination were studied with a veiw to standardizing the procedure.

EXPERIMENTAL PROCEDURE

The method of determining the water-vapor adsorption was essentially as described by Robinson, with the exception that the particular factor which was under investigation was made to vary. Approximately 2 g. of the air-dried sample which had been passed through a 0.25 mm. sieve was weighed into a shallow weighing dish of about 30 mm. diameter, provided with a ground glass stopper. The uncovered dishes were placed in a vacuum desiccator over 100 cc. of the specified strength of sulfuric acid, the desiccator evacuated, and placed in a constant temperature chamber controlled by a thermostat. At the end of the period dry air was slowly let into the desiccator while still in the constant temperature chamber, the cover removed, and the dishes covered as quickly as possible. As soon as they cooled to room temperature, the dishes were weighed, uncovered, and placed in a drying oven at 110° C. for 18 hours. At the end of this period they were removed, covered, cooled in a drying desiccator, and weighed.

OUTLINE OF INVESTIGATION

Experiments were carried out on both the soil material and the extracted colloid. The results on the soil material show the influence of the various factors on the adsorptive capacity of the colloid as it exists in the soil since Anderson, et al (1) have shown that at least 95 per cent of the adsorption of the soil material is due to the colloidal fraction. The ratio of the adsorption of the soil material to that of the colloid shows to what extent the extracted and the unextracted colloids have been affected by the different conditions.

Four factors naturally presented themselves as affecting the adsorption, (a) the length of time in which the adsorption is carried on, (b) the temperature, (c) the vapor pressure, and (d) the degree of evacuation. Each of these factors was investigated by keeping 3 factors constant while the other was allowed to vary. Several minor factors were noted during the course of the investigation, and it was possible to investigate some of these also.

EXPERIMENTAL RESULTS

Time

The first factor studied was time. No effort was made to obtain absolute equilibrium, as it has been pointed out by several investigators that it is theoretically, at least, impossible. However, the important consideration is the time necessary for the soil material and the colloid to come to equilibrium.

The samples were run first in the air-dry condition for varying lengths of time up to 7 days. The desiccators were evacuated to 30 mm. pressure, the temperature was 30° C., and the sulfuric acid used was 3.3 per cent by weight. At the end of the experiment the oven-dried samples were used for a second determination under identical conditions. The results of these determinations are shown in Table 1 and 2, respectively, and graphically in Figs. 1 and 2.

These results indicate an increase in adsorption with time up to 7 days, the limit of the experiment. In Fig. 1 it will be noted that the curves for the soil materials between 96 and 168 hours are nearly horizontal,[1] indicating practical equilibrium whereas those for the colloids still have a considerable upward trend. It may readily be seen that the curves for the colloids have a greater slope than those for the soil materials, indicating that the rate of adsorption is greater for the colloids. It is interesting to note how the curves for the colloids tend to reach approximately the same level, indicating, as pointed out by Robinson (5) the great similarity in the quantity of water adsorbed by different colloids under these conditions. However, it should be noted that the different colloids approach this point by very different rates of adsorption.

[1] The 168-hour determination on the Cecil soil is very evidently in error.

TABLE 1.—The quantity of water vapor adsorbed by air-dried soil material and colloid in various lengths of time

(3.3 per cent H_2SO_4, 30 mm. pressure at 30° C.)

Soil	Sample	Water adsorbed per gram of sample								
		Moisture content of air-dry material	1 hr.	2 hr.	4 hr.	6 hr.	24 hr.	48 hr.	96 hr.	168 hr.
		gram	gram	gram	gram	gram	gram	gram	gram	gram
Cecil clay	Soil	0.0059	0.0116	0.0140	0.0165	0.0200	0.0246	0.0296	0.0342	0.0318
loam	Colloid	.0322	.0616	.0710	.0926	.1077	.1660	.2034	.2601	.2780
Norfolk fine	Soil	.0120	.0231	.0294	.0371	.0399	.0528	.0563	.0622	.0629
sandy loam	Colloid	.0446	.0883	.1143	.1477	.1753	.2626	.3144	.3346	.3358
Clarksville silt	Soil	.0199	.0341	.0403	.0466	.0500	.0581	.0651	.0665	.0664
loam	Colloid	.0618	.1121	.1405	.1772	.1964	.2505	.2643	.2798	.2845
Sharkey clay	Soil	.0899	.1107	.1203	.1319	.1417	.1612	.1650	.1826	.1832
	Colloid	.1339	.1933	.2238	.2468	.2707	.3276	.3472	.3829	.3967

TABLE 1. (Continued).—The quantity of water vapor adsorbed by oven-dried soil material and colloid in various lengths of time

(3.3 per cent H_2SO_4, 30 mm. pressure at 30° C.)

Soil	Ratio $\frac{\text{soil}}{\text{colloid}}$ x 100								
	Air-dry material	1 hr.	2 hr.	4 hr.	6 hr.	24 hr.	48 hr.	96 hr.	168 hr.
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
Cecil clay loam	18.3	18.8	19.7	17.8	18.6	14.8	14.5	13.1	11.4
Norfolk fine sandy loam	26.9	26.2	25.7	25.1	22.8	20.1	17.9	18.5	18.7
Clarksville silt loam	32.2	30.4	28.7	26.3	25.5	23.2	24.6	23.8	23.3
Sharkey clay	66.2	57.3	53.8	53.5	52.4	49.2	47.5	47.7	46.2

Practically the same considerations hold for the oven-dry samples, except that in this case, since the curves reach practically the same levels as those for the air-dry samples, the slopes necessarily have to be greater in order to make up for the hygroscopic moisture.

The ratio of the adsorption of the soil material to that of the colloid, which is used for estimating the quantity of colloidal material in the soil, is based on an adsorption period of 5 days. The data in Tables 1 and 2 indicate that, for both the air-dry and oven-dry samples, the ratio is practically constant for the 3 samples other than those representing the Cecil soil after 48 hours. The Cecil soil material practically reaches equilibrium in 96 hours, and taking everything into consideration, it is recommended for purposes of colloidal estimation that the adsorption be carried on for at least 5 days.

Temperature

The effect of temperature on adsorption was studied with particular regard to its effect on the quantity of colloid that may be estimated.

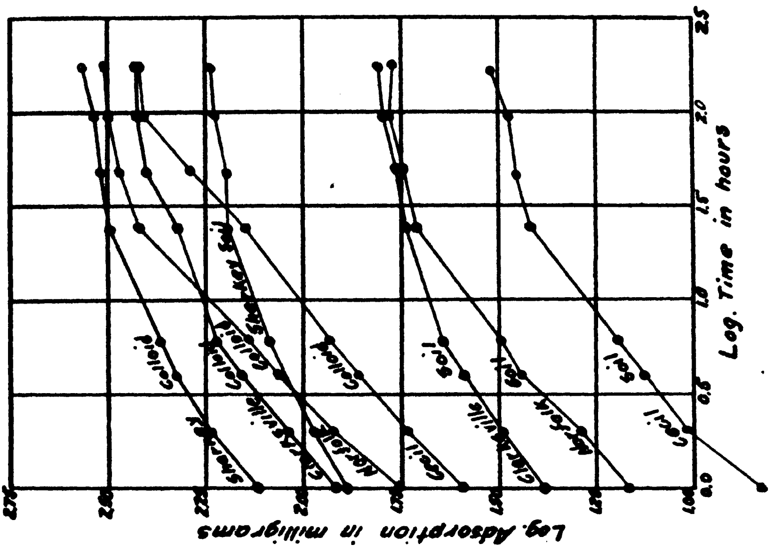

Figure 2.—The quantity of water vapor adsorbed by oven-dried soil material and colloid in various lengths of time

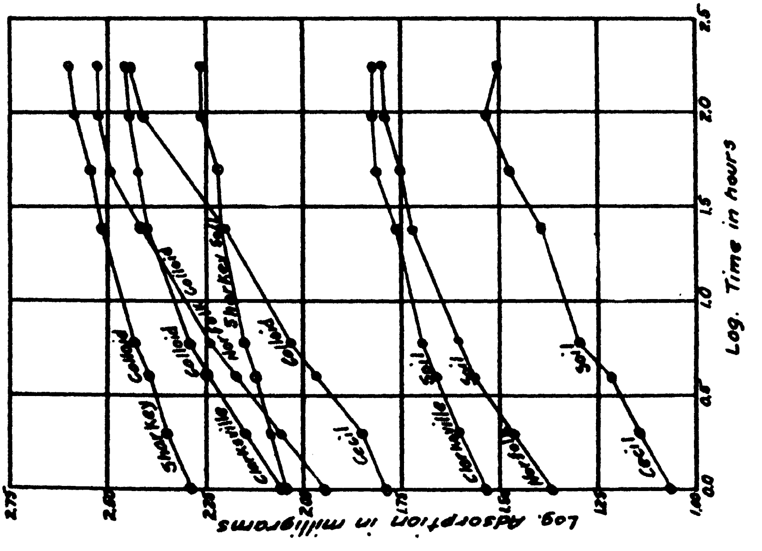

Figure 1.—The quantity of water vapor adsorbed by air-dried soil material and colloid in various lengths of time

The constant temperature chamber used in this and previous investigations has no provision for operation at a temperature lower than room temperature, and it operates best at a temperature a few degrees above

TABLE 2.—The quantity of water vapor adsorbed by oven-dried soil material and colloid in various lengths of time

(3.3 per cent H_2SO_4, 30 mm. pressure at 30° C.)

Soil	Water adsorbed per gram of sample								
	Sample	1 hr.	2 hr.	4 hr.	6 hr.	24 hr.	48 hr.	96 hr.	168 hr.
		gram	gram	gram	gram	gram	gram	gram	gram
Cecil clay loam	Soil	0.0067	0.0104	0.0134	0.0155	0.0264	0.0285	0.0300	0.0331
	Colloid	.0391	.0542	.0716	.0852	.1749	.1943	.2545	.2622
Norfolk fine sandy loam	Soil	.0148	.0195	.0278	.0311	.0515	.0549	.0598	.0588
	Colloid	.0564	.0836	.1158	.1367	.2640	.2927	.3147	.3194
Clarksville silt loam	Soil	.0241	.0310	.0385	.0439	.0544	.0575	.0625	.0637
	Colloid	.0823	.1105	.1441	.1656	.2408	.2509	.2650	.2662
Sharkey clay	Soil	.0771	.0943	.1120	.1226	.1566	.1571	.1673	.1715
	Colloid	.1293	.1726	.2117	.2312	.3137	.3270	.3407	.3635

TABLE 2. (Continued).—The quantity of water vapor adsorbed by oven-dried material and colloid in various lengths of time.

(3.3 per cent H_2SO_4, 30 mm. pressure at 30° C.)

Soil	Ratio $\frac{\text{soil}}{\text{colloid}}$ x 100							
	1 hr.	2 hr.	4 hr.	6 hr.	24 hr.	48 hr.	96 hr.	168 hr.
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
Cecil clay loam	17.1	19.2	18.7	18.2	15.1	14.7	11.8	12.6
Norfolk fine sandy loam	26.3	23.3	24.0	22.8	19.5	18.8	19.0	18.4
Clarksville silt loam	29.3	28.0	26.7	26.5	22.6	22.9	23.6	23.9
Sharkey clay	59.6	54.6	52.9	53.0	50.0	48.1	49.1	47.2

room temperature. For the greater part of the year in this locality, a temperature of 30° C. is satisfactory, but in midsummer it is necessary to raise the temperature to 35° C. and to lower it to 25° C. in midwinter. It was important, therefore, to know whether results obtained at these different temperatures would be comparable. Data on this point are given in Table 3.

These results indicate that for the soil colloids there is a slight increase in the adsorption with the temperature, whereas for the soil materials the adsorption is irregular. The ratios are practically constant for the different temperatures. When it is taken into consideration that the determinations were of necessity made at rather wide intervals, they may be considered very good duplicates.

Vapor Pressure

The effect of vapor pressure on adsorption was studied by varying the strength of the sulfuric acid used in the desiccators from 0 to 43 per cent by weight. The determinations over pure water are unreliable, owing to

TABLE 3.—Effect of temperature on the adsorption of water vapor by soil materials and colloids

(*3.3 per cent H_2SO_4. 30 mm. pressure for 96 hr.*).

Soil	Sample	Water adsorbed per gram of sample			Ratio $\frac{\text{soil}}{\text{colloid}}$ x 100		
		25° C.	30° C.	35° C.	25° C.	30° C.	35° C.
		gram	gram	gram	per cent	per cent	per cent
Cecil loam	Soil	0.0350	0.0334	0.0354	10.8	10.2	10.6
	Colloid	.3246	.3273	.3354			
Clarksville silt loam	Soil	.0643	.0645	.0667	24.3	24.0	24.3
	Colloid	.2646	.2685	.2748			
Miami silty clay loam	Soil	.1439	.1370	.1439	55.0	51.6	53.2
	Colloid	.2616	.2656	.2707			
Stockton clay adobe	Soil	.1661	.1566	.1608	52.2	48.9	49.7
	Colloid	.3183	.3205	.3234			

condensation caused by the slight changes of temperature in the constant temperature chamber. If it is assumed that the condensation in each case is equal, the result will be that the ratio of the adsorption of the soil material to that of the colloid will be higher than it should be. For example, let x be the quantity of water adsorbed by the soil, y the water adsorbed by the colloid, and a the quantity of water condensed. Then, since y is always greater than

$$x, \frac{x+a}{y+a} > \frac{x}{y}.$$

The only purpose in using the sulfuric acid is to depress the vapor pressure at $T°$ C. to a point equal to or less than complete saturation at (T–t)° C. where t is the change in temperature in the constant temperature chamber, in order that no condensation take place. The constant temperature chamber used in this work had a variation in temperature of less than 0.1° C., and it has been calculated that the water vapor over 3.3 per cent sulfuric acid by weight at 30° C. will be just saturated at a temperature of 29.9° C. The results of this investigation are shown in Table 4.

The results in Table 4 indicate that the adsorption of both the soil material and colloid decreases very greatly with a decrease in the vapor pressure, owing to the increase in the strength of the sulfuric acid. However, the ratio of the adsorption of the soil material to the absorption of the colloid shows a marked increase, particularly with the higher-strength acid. This indicates that the degree of adsorption in case of the colloid is proportionately less than that of the soil material under these conditions, which is just opposite the effect of the length of time, as shown above where the colloid had a slightly higher rate of adsorption and a decrease

in the ratio. This indicates that, by varying both factors simultaneously, a point might be determined where the rate of adsorption of the soil material and the extracted colloid would be in equilibrium. Preliminary

TABLE 4.—Effect of vapor pressure on the adsorption of water vapor by soil materials and colloids

(30 mm. pressure, 120 hr. at 30° C.)

Soil	Water adsorbed per gram of sample								
	Sample	0.0	2.0[a]	5.0	7.5	10.0	16.0	30.0	43.0
		gram	gram	gram	gram	gram	gram	gram	gram
Cecil clay loam	Soil	0.0474	0.0368	0.0296	0.0259	0.0216	0.0158	0.0072	0.0058
	Colloid	.3428	.2933	.2294	.1798	.1361	.0959	.0446	.0291
Norfolk fine sandy loam	Soil	.0775	.0669	.0544	.0525	.0464	.0355	.0172	.0103
	Colloid	.3729	.3449	.3163	.2981	.2541	.1806	.0766	.0462
Clarksville silt loam	Soil	.0802	.0720	.0613	.0569	.0531	.0459	.0257	.0195
	Colloid	.3187	.2958	.2697	.2524	.2363	.1994	.1098	.0678
Sharkey clay	Soil	.2171	.1905	.1671	.1547	.1442	.1289	.0928	.0696
	Colloid	.4728	.4125	.3552	.3243	.2997	.2646	.1805	.1293

[a] Per cent H_2SO_4 by weight.

TABLE 4. (Continued).—Effect of vapor pressure on the adsorption of water vapor by soil materials and colloids

(30 mm. pressure, 120 hr. at 30° C.)

Soil	Ratio $\frac{\text{soil}}{\text{colloid}} \times 100$							
	0.0	2.0	5.0	7.5	10.0	16.0	30.0	43.0
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
Cecil clay loam	13.8	12.5	12.9	14.4	15.9	16.5	16.1	19.9
Norfolk fine sandy loam	20.8	19.4	17.2	17.6	18.3	19.7	22.5	22.3
Clarksville silt loam	25.2	24.3	22.7	22.5	22.5	23.0	26.1	28.8
Sharkey clay	46.0	46.2	47.1	47.7	48.1	48.7	51.4	53.8

experiments along this line indicate considerable variation in this point in the case of different soils.

Pressure

The effect of the pressure at which the adsorption was carried on was investigated primarily on account of the results which were obtained from a desiccator which was known to have leaked, and which were at considerable variance with other determinations. It is quite evident, however, that an increase of the pressure in the desiccator will decrease the quantity of water vapor adsorbed in a given time for various reasons, among which is the retardation of the movement of the water vapor owing to the presence of a greater number of air molecules.

TABLE 5.—Effect of pressure on the quantity of water vapor adsorbed by soil materials and colloids

(3.3 per cent H_2SO_4, 30° C. for 96 hr.)

Soil	Sample	Water adsorbed per gram of sample				Ratio $\frac{\text{soil}}{\text{colloid}}$ x 100			
		30 mm.	50 mm.	100 mm.	200 mm.	30 mm.	50 mm.	100 mm.	200 mm.
		gram	gram	gram	gram	per cent	per cent	per cent	per cent
Cecil clay loam	Soil	.0350	.0367	.0315	.0288	12.0	13.7	14.2	16.5
	Colloid	.2912	.2686	.2226	.1744				
Norfolk fine sandy loam	Soil	.0641	.0620	.0622	.0572	18.9	19.0	19.1	21.2
	Colloid	.3383	.3363	.3250	.2700				
Clarksville silt loam	Soil	.0687	.0665	.0656	.0608	23.8	23.7	23.7	23.6
	Colloid	.2885	.2803	.2766	.2567				
Sharkey clay	Soil	.1896	.1833	.1737	.1630	46.5	47.5	51.5	50.0
	Colloid	.4089	.3872	.3373	.3274				

The above results indicate a wide variation in the adsorption of the samples under different pressures. For example, between 30 mm. and 200 mm. the quantity of water adsorbed by the Cecil colloid is decreased 40 per cent, whereas in case of the Clarksville colloid the decrease is only 11 per cent. Similarly, the ratio for the Clarksville soil shows a slight decrease with increase of pressure, whereas the others, particularly that for the Cecil soil, show an increase. The effect of increase of pressure on the ratio is very similar to the effect of decrease of vapor pressure. The results for 200 mm. correspond rather closely with those for 16 per cent sulfuric acid given in Table 4. These results show the necessity of using desiccators which do not leak in order to get comparable results.

Size of Colloidal Aggregate

It has been noted that in some cases the extracted colloid has a higher rate of adsorption, and in some cases a lower rate, than the colloid in the soil, as measured by the adsorption of the soil material. Robinson (6) has pointed out that the size of the colloidal aggregates has little if any effect on adsorption. However, it was thought best to determine if possible whether the results noted above were due to the size of the aggregate or because the extracted colloid may not be representative of all of the colloid in the soil as shown by Gile (3). In order to determine whether there is any difference in the adsorption due to the size of the aggregate, a sample of Sharkey colloid and Sharkey soil were passed through a 0.25 mm. sieve and their adsorptions compared with that of a sample of Sharkey colloid the aggregates of which were between 1 and 2 mm. in diameter and

with that of a sample which had been passed through a 0.1 mm. sieve. In addition to this, Sharkey colloid and quartz flour were mixed in equal proportions by weight (on the oven-dry basis), thoroughly puddled, allowed to air-dry, and passed through a 0.25 mm. sieve. The results of these determinations are shown in Table 6.

TABLE 6.—Effect of the size of colloidal aggregate on the adsorption of soil colloids (30° C. 30 mm. pressure at 120 hr.)

Sample	Adsorption per gram				Ratio $\frac{\text{soil}}{\text{colloid}}$ x 100			
	3.3 per cent H_2SO_4	10 per cent H_2SO_4	30 per cent H_2SO_4	43 per cent H_2SO_4	3.3 per cent H_2SO_4	10 per cent H_2SO_4	30 per cent H_2SO_4	43 per cent H_2SO_4
	gram	gram	gram	gram	per cent	per cent	per cent	per cent
Sharkey soil .25 mm.	0.1888	0.1479	0.0925	0.0691				
Sharkey colloid .25 mm.	.4090	.3072	.1783	.1298	46.2	48.2	51.9	53.2
Sharkey colloid 2–1 mm.	.3994	.3087	.1837	.1291	47.3	47.9	50.4	53.5
Sharkey colloid .1 mm.	.4157	.3160	.1798	.1244	45.4	46.8	51.4	55.6
Sharkey colloid + quartz flour .25 mm.	.2050	.1553	.0887	.0615	46.1 [a]	47.6	52.2	56.2

[a] Based on twice the recorded adsorption due to 50 per cent dilution of the colloid with quartz flour.

These results indicate very slight differences in the adsorption owing to the size of the colloidal aggregates. It is probable that any change in adsorptive capacity would occur in microscopic aggregates rather than in macroscopic aggregates which were used in these determinations. However, it may be noted that the sample less than 0.1 mm. had the highest adsorption over 3.3 per cent acid and the lowest over 43 per cent acid, and that diluting the colloid with quartz flour indicated no appreciable alteration in the adsorption. The conclusion drawn from this and previous determinations is that the change in the rate of adsorption of extracted colloid, as compared with the adsorption of the colloid in the soil material may be explained by the fact that the extracted colloid is not wholly representative of the colloid in a soil, and that there has been alteration in the adsorptive capacity of the colloid on extraction.

GENERAL DISCUSSION

It has been shown how various factors influence the adsorption of water vapor by soil colloids. The colloid extracted from the soil material behaved differently under different conditions than the unextracted colloid in the soil material. For example it takes a longer time for the extracted colloid to come to practical equilibrium than it does for the

unextracted colloid. This and other differences may be explained by the fact that the adsorptive capacity of the colloid is altered on extraction, although it is possible to determine the extent of this alteration and allow for it, which has been demonstrated in other investigations, it is a tedious process and for this reason the use of the average adsorption factor is recommended since the results in general are comparable to those obtained by this method.

Since the primary purpose of this investigation was to standardize the procedure for estimating the quantity of colloid in the soil by means of the average adsorption factor, it may be well to consider the effect on this determination of the various factors studied. As regards the length of time, the results indicate that at least 5 days are necessary. Probably very little would be gained in allowing a longer time than this unless exceptionally good vacuum desiccators are available, which will maintain the required vacuum for a longer period. The strength of the sulfuric acid to be used is an important consideration. The more nearly the strength of the acid approaches zero the more nearly the adsorptions of the different colloids approach the same value. However with the apparatus available in this investigation satisfactory results were not obtained below 3.3 per cent acid. It was found that temperature between 25° and 35° C. had very little effect on the adsorption. However, it is important that the pressure be kept low. Thirty mm. pressure is recommended because it is very near the boiling point of the acid solution at ordinary temperatures.

SUMMARY

The effect of time, vapor pressure, temperature, degree of vacuum, and size of aggregate on the adsorption of water vapor by soil colloids both in the extracted and unextracted state was determined. From these results it is recommended for the purpose of estimating the quantity of colloid in the soil material that the determination of the adsorption of the soil material be made over 3.3 per cent (2 per cent by volume) sulfuric acid, at 30 mm. pressure, for at least 5 days, at a temperature between 25° and 35° C. and that an average factor be used for the adsorption of the colloid.

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INFLUENCE OF AIR-DRYING OF SOILS ON THEIR CONTENT OF FINEST PARTICLES

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The soil samples to be analyzed mechanically and chemically are usually first air-dried and then passed through a 2 mm. sieve. The so-called fine soil which is used for all pedological and bacteriological work is prepared in this way. The results of many analyses of fine soil so prepared do not agree closely with the results obtained upon the fresh soil. Sometimes these differences reach noticeable values.

(1) The hygroscopicity of the fresh soil is with a very few exceptions higher than that of the air-dried soil. In Table 1 are included a few examples.

TABLE 1.—Hygroscopicity of fresh and air-dried soil

Horizon of podsol	Soil	
	Fresh	Air-dried
A_1	15.65	12.00
A_2	3.95	3.10
B	9.89	8.30
C	5.02	4.00

The foregoing data show us that the difference between the results is noticeably higher than the probable analytical error.

(2) The hydrogen-peroxide-catalase changes also through the air-drying of the soil. A few examples are cited in Table 2.

(3) The manner in which the air-drying of soil acts on the setting free of plant nutrients and how this influences the stage of growth of the plants, likewise how the amount of salts easily soluble in water increases, is partly explained by the work of Gustaffson, Lebediantzeff, Vanha and others.

(4) The absorption by the soil of the ammonium ion decreases according to the decrease in the hygroscopicity which also has been found by others to vary with the pH value (1, 2, 3).

All this led us to assume that the results of the mechanical analyses will vary also if we start with the fresh or air-dried soil.

We determined the percentage of the clay (0.002 mm.) in the fresh and air-dried soil. The samples were soaked in distilled water for 24 hours

TABLE 2.—Effect of air-drying soil upon hydrogen-peroxide-catalase

Horizon of podsol	Soil			
	Fresh		Air-dried	
	Time	cc.mol.O_2	Time	cc.mol.O_2
	min.		min.	
A_0	5	72.3	5	52.0
	10	98.0	10	78.0
A_1	5	35.4	5	14.0
	10	40.5	10	18.2
A_2	5	40.8	5	21.0
	10	53.2	10	29.2
B	5	70.8	5	48.3
	10	95.6	10	72.3
B_1	5	70.0	5	47.0
	10	96.5	10	72.0

then boiled ½ hour, rubbed with a rubber finger and the turbid liquid was allowed to settle in glass cylinders (when the fresh and air-dried soils were treated with strong chemicals such as HCl and H_2O_2 the results did not vary perceptibly). The results tabulated in Table 3 will show the average differences of six determinations:

TABLE 3.—Determination of clay in soil

Horizons	Per cent of clay in soil	
	Fresh	Air-dried
A_1	11.90	8.00
A_2	19.05	12.20
B	30.70	24.02
C	8.30	6.52
A_1	15.00	11.11
A_2	20.53	15.10
B_1	39.70	31.04
B_2	21.30	17.02
C	15.30	11.03

When we determined the particles finer than coarse clay, the data showed greater differences. Because of the fact that mostly coarse clay only is estimated we are not going to cite here the results of the finer separations.

We think that for highly accurate work, especially where stress is laid upon the finest particles, one should use only the fresh soil samples.

Some kinds of the Rendzina soils furnish very different results in the

amount of clay obtained depending upon whether we take the fresh or air-dried soil for the analysis.

It is to be noted that the data of the fresh soils depict the nature of the soils (it would be of great interest to consider the "adobe" soil) better than do the results of the air-dried soils.

It will be of prime importance to call attention to this fact in the estimation of colloid clay; so far of course stronger chemical treatment has not been used.

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THE MOVEMENT OF GROUND AND SOIL WATERS[1]

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In order to simplify the study of the complex process of the movement of ground and soil waters, the author considers it expedient to investigate the individual phases of this process, namely: (1) The movement of water in the form of vapor (3). (2) The movement of water in the liquid phase (4). (3) The movement of water in the solid phase.

The author investigated a series of phenomena connected with the vapor and liquid phase of soil and ground waters but for certain reasons

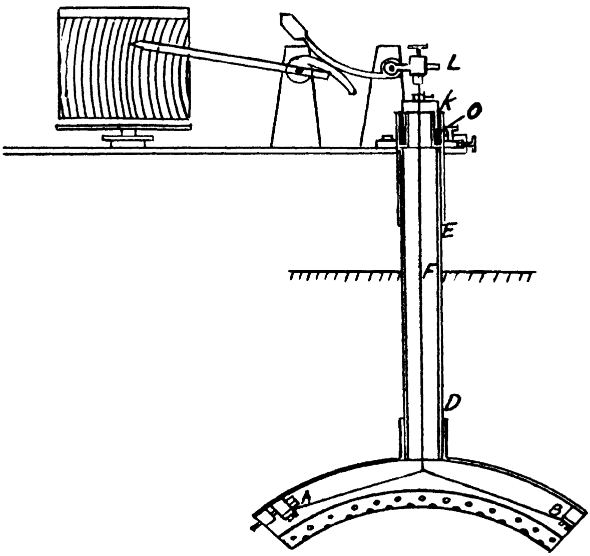

Figure 1.—A hair hygrograph for the study of the relative humidity of the soil air

the phenomena of the movement of the solid phase has not been touched upon.

For the study of the vapor phase an apparatus has been constructed for the determination of the relative humidity of the soil air. This apparatus represents a modification of the hair hygrograph of the Rishar construction (fig. 1). The hair A B protected by a special tube may be inserted in the soil. The tube is connected with a self-recording part of the hygro-

[1] A concise statement of the two papers by the author.

[2] Translated from the Russian manuscript by J. S. Joffe, New Jersey Agr. Expt. Sta.

graph by means of a glass tube D E. The hair of the hygrograph is attached to a lever of the self-recording mechanism L by means of a thin wire F made from nickel steel. The bell K suspended on the wire F is floating in the oil O preventing the atmospheric air entering the soil through tube D E. The apparatus is calibrated by the psychrometer of Asman. The calibration was made before and after the experiment.

The hair of the above described hygrograph was placed in the soil kept in boxes at a constant temperature. The moisture content of the soil varied from experiment to experiment within wide limits. These investigations have shown that: (1) If the soil contains moisture in an amount greater than the maximum hygroscopicity, then the relative humidity of the soil air equals 100. One of the experiments illustrates this.

Table 1 gives the results of the experiment.

The maximum hygroscopicity of chernozem (7.35 per cent), podsol (3.18 per cent) and sand (0.41 per cent) varies as may be seen within very wide limits and still the relative humidity of the air in these soils is intimately connected with it.

TABLE 1.—Relation between moisture content and relative humidity of the soil air in chernozem, podsol and sand

Chernozem [a]		Podsol [b]		Sand [c]	
7.35 Per cent		3.18 Per cent		0.41 Per cent	
Moisture content	Relative humidity of the soil air	Moisture content	Relative humidity of the soil air	Moisture content	Relative humidity of the soil air
per cent	per cent	per cent	per cent	per cent	per cent
15.27	100	12.51	100	8.15	100
11.44	100	8.45	100	5.79	100
8.07	100	5.13	100	2.21	100
7.10	94	3.32	100	1.34	100
5.62	68	3.07	95	0.62	100
4.43	49	2.16	73	0.32	69

Maximum hygroscopicity of soil: [a] 7.35; [b] 3.18; [c] 0.41 per cent.

Investigations on the relative humidity of soil air when the soil moisture is lower than its hygroscopicity have shown that the soil air in such soils is not saturated with water vapor and its relative humidity is less than 100 per cent. (2) The drier the soil is the less the relative humidity of its air; (3) with the moisture content of the soil remaining constant the relative humidity of the air increases with an increase in the temperature of the soil and vice versa. The following Table 2 illustrates points 2 and

3. The soil was an Odessa chernozem; its maximum hygroscopicity 5.62 per cent.

TABLE 2.—Moisture, relative humidity of the soil air, and temperature of soil from Odessa

Soil moisture	Temperature	Relative humidity of soil air
per cent	°C.	per cent
5.43	10	94
	17	95
	45	99
	70	99
3.99	17	81
	35	86
	50	92
	60	98
2.43	10	39
	21	41
	45	51
	60	57

Observations on the relative humidity of soil air in nature have shown that soil air under natural conditions is always saturated with water vapor below the depth of 5 to 10 cm. The vapor pressure of the soil may therefore be correlated with its temperature. In the upper layer which is being dried to a point lower than its maximum hygroscopicity the soil air does not reach complete saturation and the vapor pressure is less the drier the soil is and the lower its temperature.

A study of the relation between the vapor pressure in the soil and in the atmosphere has shown that in the soil the vapor pressure throughout the year is greater than in the atmosphere. This is clearly illustrated in Table 3. (An Odessa chernozem soil).

From the example given it may be seen that in the soil and in the upper layers of the ground throughout the year there is a more or less thick zone where the vapor pressure is greater than that of the atmosphere. This alone is sufficient to recognize as untenable the theory of Volger on the formation of ground waters by condensation of water vapor of the atmosphere in the deeper layers of the ground (1).

However, an investigation of the relation of the water vapor in the very upper layer of the soil (a depth of ½ to 1 cm.) during the night shows that very often there are occasions when the absolute humidity of the atmosphere is greater than the vapor pressure in the upper layer of the soil. Thus, for instance, on the 9th of July, 1898 the temperature of the upper layer of the soil dropped to 13.9°; the maximum vapor pressure corresponding to such a temperature equals 11.8 mm. During the night, from

TABLE 3.—Relation between vapor pressure in the soil and in the atmosphere

Month and date	April 15 (Spring)		June 15 (Summer)		September 30 (Fall)	
Time	7 A.M.		1 P.M.		9 P.M.	
Absolute humidity of the atmosphere	6.6 mm.		12.9 mm.		8.0 mm.	
Soil	Soil		Soil		Soil	
Depth of soil	Temperature	Vapor pressure	Temperature	Vapor pressure	Temperature	Vapor pressure
cm.		mm.		mm.		mm.
0	11.0	9.8	51.5	99.1	11.7	10.3
10	10.4	9.4	33.4	36.2	21.0	18.5
20	10.6	9.5	29.2	30.1	21.4	19.0
40	10.7	9.6	23.9	22.0	20.5	17.9
80	9.6	8.9	21.0	18.5	20.6	18.1
160	8.3	8.2	17.6	15.0	19.8	17.2
200	8.1	8.1	16.3	13.8	19.2	16.4
250	8.0	8.0	14.7	12.5	18.0	15.4
320	9.0	8.6	13.4	11.4	17.0	14.4

12 to 6 A. M., the absolute humidity of the air is equivalent to from 16.4 to 17.8 mm. Under such conditions the atmospheric vapor must enter the soil under the influence of the difference in vapor pressure between that of the atmosphere and the soil and condense in the soil.

These relations have been studied in detail from the data of the meteorological observatory of the University of Odessa for a period of 3 years, 1896, 1897, 1898. The number of days during the year when the process of condensation of the water vapor of the atmosphere in the upper layer of the soil took place varied with the year and month as may be seen from the following Table 4.

TABLE 4.—Number of days during the year when condensation occurred

Month.	March			April			May			June			July			August			September			October			November			For entire year
Index.	+	±	—	+	±	—	+	±	—	+	±	—	+	±	—	+	±	—	+	±	—	+	±	—	+	±	—	+
Year																												
1896	23	1	7	26	3	1	12	10	9	5	9	16	5	14	12	8	11	12	13	6	11	22	4	5	18	8	4	126
1897	26	3	2	21	8	1	22	7	2	19	7	4	12	10	9	4	7	20	19	6	5	16	7	8	23	2	5	162
1898	24	3	4	20	7	3	26	4	1	17	11	2	23	7	1	8	8	15	13	7	10	25	3	3	23	3	4	179

The intensity of the process of condensation is determined in its first proximity on the basis of 36 observations made in Odessa from April to

October. During 6 out of the 36 nights there was no condensation; during the others the soil was enriched with moisture. The observations were made on small tumblers (5 cm. high; 3 cm. dia.). The soil was placed into the tumblers flush with the top; it had a moisture content greater than its maximum hygroscopicity. Therefore the vapor pressure in the soil was at its maximum. The tumblers were weighed before sunset and pushed into the ground in the open in such a manner that the soil in the tumbler was on the same level as the surrounding soil. The nights chosen were calm and without dew. At sunrise second weighings were made and it is these weighings that showed the presence or absence of condensation. The absolute gain of water was calculated in millimeters as is generally adopted in meteorological observations. Figuring for the Odessa zone 200 nights in the year during which condensation may take place, with 0.36 mm. of water condensed per night, then the soil in that region obtains water above its precipitation about 72 mm. in the year. With a precipitation of 400 to 450 mm. per year in the southern steppe such an intensive process of condensation must be looked upon as considerable.

THE HYDROLOGICAL SIGNIFICANCE OF THE UPPER LAYER OF THE SOIL

Under natural conditions the enrichment of the soil with water of condensation must be greater than what has been found in the experiments reported, since during the spring, summer and part of the fall the moisture content of the upper layer of the soil drops very frequently to a point lower than its maximum hygroscopicity. Under such conditions the vapor pressure in the soil is lower than the maximum vapor pressure at a given temperature and therefore the difference between the absolute humidity of the air and the vapor pressure in the soil (condensation potential) is greater whereby the intensity of condensation increases. In nature a very dry surface layer of the soil plays a very important hydrological rôle. Because of it the soil, in process of water evaporation, not only loses water but also gains some during the dry periods when the upper layer seems to be dead. The aforesaid is very well illustrated by observations on the moisture content of the upper layer of the soil at a depth of 1 cm. made on the 27th and 28th of July in a dry year at the Yekaterinosfav Agricultural Experiment Station as shown in Table 5.

TABLE 5.—Average moisture content of the soil in per cent (25 observations)

July 27			July 28	
12 M.	4 P.M.	8 P.M.	4 A.M.	4 P.M.
2.40	1.99	3.49	5.26	1.93

Within 12 hours the moisture content of the upper layer increased by 3.25 per cent. The night was dry and the relative humidity of the atmosphere for the entire period of observation fluctuated between 50 and 92 per cent. Such an increase in moisture content of the upper layer during one night in the dry season of the year must, to a certain degree, diminish the injury of drought in the dry region, since part of the moisture obtained at night by the upper layer will be transmitted during the day to the lower layers. One cannot figure that all the moisture obtained by the upper layer of the soil is condensation moisture from the atmosphere. A part of it undoubtedly moved into the upper layer from a lower layer of the soil. But in this case the upper layer of the soil surface plays the part of a protection layer against rapid drying and this gives a still greater hydrological significance to this phenomenon.

In connection with the daily fluctuations of the soil temperature the vapor pressure in the various horizons changes. For a given value of vapor pressure there is a corresponding movement of water in the form of vapor from one horizon of the soil into the other. Figure 2-A illustrates the daily trend of the vapor pressure in soils during the summer at a depth of 5, 10 and 20 cm. From 4 to 7 P.M. up to 7 to 8 A.M. the vapor pressure at a depth of 10 cm. is greater than at a depth of 5 to 20 cm. Therefore, the water is being distilled over from the 10 cm. depth upward and downward, and the intermediary layer is drying up. From 7 to 8 A.M. to 4 to 7 P.M. the vapor pressure at a depth of 5 cm. is greater than at a depth of 10 cm. and for this reason the water is being distilled from the upper layer into the lower one. Since in the most upper layer such a relation of the vapor pressure exists, then this layer suffers a double evaporation: into the atmosphere—this is a well known process of evaporation—and into the deeper layers of the soil (see Table 3, 15th of June, 1 P.M.). The water being distilled into the lower layers is condensed and increases the resources of the liquid water. Thus the atmospheric vapor absorbed by the soil in the process of condensation, as well as the water that moved in the vapor form from the lower layers the night before and retained by the upper layer, are to be considered as physiologically useful water which in part unite with those of the lower layers; these may be used by the plants.

If during the summer (fig. 2-B) a cold spell comes on and the surface of the soil is cooled off, a movement of the water in the form of vapor into the upper layers may be observed; the lower layers of the soil lose therefore part of their water. With the oncome of a hot spell the water drawn up to the surface will be lost by the soil and thus a cold spell during the summer not accompanied by rain may be inducive to a more energetic drying up of the lower layers of the soil.

The phenomenon of the movement of water from the lower into the upper layers during a cold spell in the summer time is more distinctly

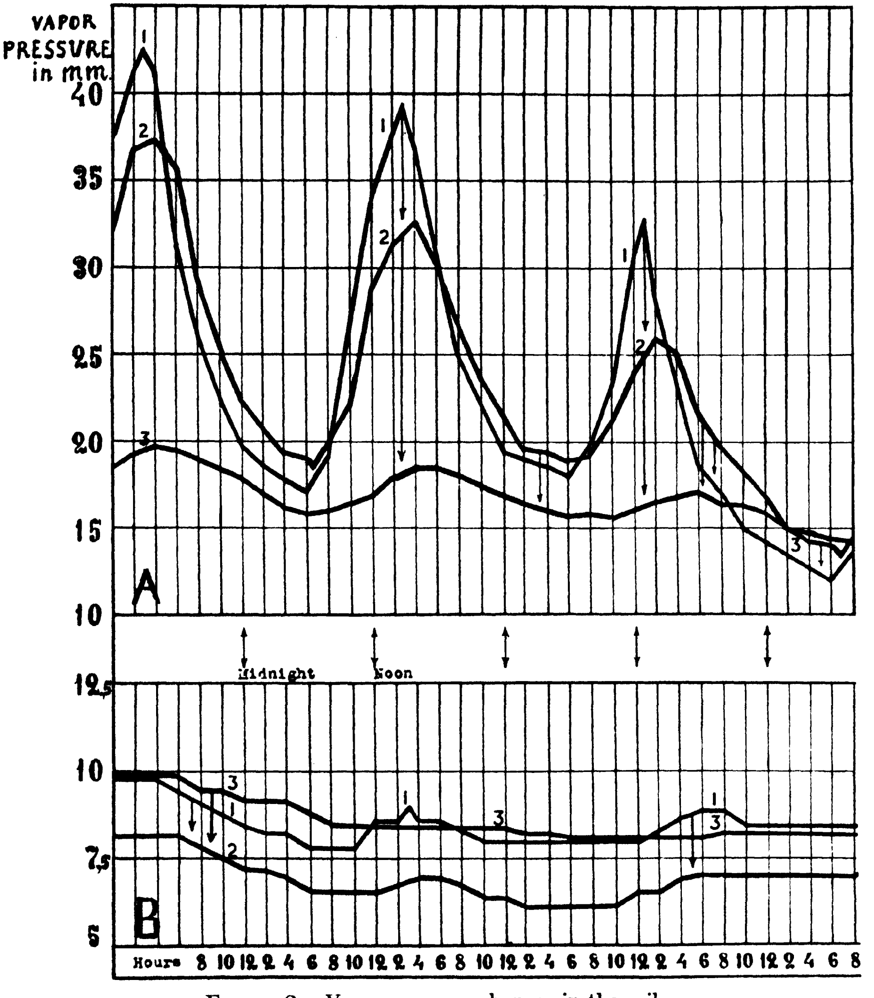

FIGURE 2.—Vapor pressure changes in the soil

Curve 1, a depth of 5 cm.
Curve 2, a depth of 10 cm.
Curve 3, a depth of 20 cm.

Graphs cover a period of 3 days:

A. In hot weather
B. In cold weather

noticeable during the winter. In the winter time the upper horizons of the soil are greatly cooled off; on the other hand the deeper layers possess a comparatively high temperature. The vapor pressure adjusts itself in accordance with the temperature of the soil and deeper down it will be greater. The aforesaid is illustrated in the following Table 6.

TABLE 6.—The distribution of temperature and vapor pressure of the soil in January at 7 A.M.

Depth of soil	Temperature	Vapor pressure
cm.	°C.	mm.
0.0	−9.8	2.1
10	−4.5	3.3
20	−3.7	3.5
40	−1.1	4.2
80	2.5	5.5
160	7.0	7.5
200	8.8	8.5
250	10.2	9.3
320	12.1	10.5

It may be seen that during the winter the vapor must move from the deeper horizon of the soil into the overlying horizon and condense, thereby enriching these layers with liquid water. The intensity of this process was determined by the author during the winter of 1914 and 1915 in Odessa. These observations were made in the following way: On uniformly level plots, determinations were made of (a) the water content in a 2 m. layer of the soil at various periods, (b) the evaporation of the water by the soil and (c) the amount of precipitation during the corresponding periods. The soil moisture was determined in per cent for each 5 cm. layer from 4 parallel borings, and it was calculated in millimeters on the basis of the volume-weight of the soil. The evaporation of moisture from the soil was determined by the evaporimeter of Vild, since special experiments have shown that evaporation from a wet soil was equal to the evaporation from a free water surface (see also paragraph 1). The resultant is that if the soil moisture is greater than its maximum hygroscopicity then the soil is filled with air saturated with vapor. The following observations illustrate this (Tables 7, 8, 9). The evaporation was observed on various soils, with various moisture contents, placed in tumblers (6 cm. high, 3 cm. dia.), kept in a thermostat. Such experiments must be of short duration, to prevent formation of an upper layer with a moisture content lower than the maximum hygroscopicity.

The maximum hygroscopicity in experiment 7 and 8 was 5.12 per cent. The evaporation drops rapidly when the soil moisture becomes lower than its maximum hygroscopicity.

TABLE 7.—Moisture content and evaporation of various soils [a]

Moisture content of the soil at end of experiment	Absolute amount of evaporation	Evaporation per sq. cm.
per cent	grams	gram
35.20	2.1756	0.329
27.53	2.2038	0.312
20.05	2.4204	0.331

[a] The time period of the experiment was 44. The vapor pressure in the soil was 26.5 mm. The absolute humidity of the air in the thermostat 8.1 mm.

The amount of precipitation was determined with the aid of 3 rain gauges located on the plot. The observations were made at the Meteorological Observatory of the University of Odessa. The results of the observations are summarized in Table 10.

TABLE 8.—Moisture content and evaporation of various soils [a]

Moisture content of the soil at end of experiment	Absolute amount of evaporation	Evaporation per sq. cm.
per cent	gram	gram
21.12	0.2982	0.046
10.74	0.2604	0.040
6.61	0.2748	0.042
2.69	0.0224	0.003
water	0.2739	0.042

[a] Time period of the experiment was 4 hours. The vapor pressure in the soil was 26.5 mm. The absolute humidity of the air was 9.3 mm.

TABLE 9.—Evaporation from several soil types [a]

Type of soil (in these observations the soil moisture was equal to 14 to 17 per cent)	Absolute amount of evaporation	Area of evaporation	Evaporation per sq. cm.
	gram	sq. cm.	mg.
Chernozem with 10 per cent humus	0.2644	5.52	46.1
Clay	0.2755	5.94	46.2
Chernozem with 4 per cent humus	0.3162	6.61	47.8
Sand from sand dunes	0.2750	5.94	46.5
Podsol from horizon B	0.2683	5.72	46.9
Loess	0.2658	5.72	46.5
Water (control)	0.3059	6.61	46.3

[a] The time period of the experiment was 4 hours. The absolute humidity of the air was 6.5 mm. The vapor pressure of the soil was 55 mm.

TABLE 10.—Meteorological observations of experiments 7 and 8

Observation	From October 26 to December 16	From December 16 to March 1	From October 26 to March 1
	mm.	mm.	mm.
1. Observed increase of water in soil	70.9	109.7	180.6
2. Amount of water evaporated from the soil	23.6	31.5	55.1
3. Actual increase of water in the soil (the sum of 1 and 2)	94.5	141.2	235.7
Amount of precipitation	49.8	119.7	169.5
Water moved from the deeper horizons in the form of vapor	44.7	21.5	66.2

The intensity of the movement of the water in vapor form from the lower horizon of the soil and ground into the upper is expressed by the figure 66.2 mm. for the winter period. With 400 to 450 mm. of precipitation for the south Russian steppe the value obtained is considerable. During the winter of 1922 and 1923 the observations described were repeated at the Rostov on Don Experiment Station (5). The observations on 3 fields—April fallow, spring wheat and corn—have shown that the average intensity of the process under consideration for the period from the 7th of October to the 6th of March was 66 mm. The existence of such a process has been confirmed by S. I. Tiuremnov for the Kuban region (9) and by V. A. Dubjanskii and B. P. Orlov for the Karakum sand desert in Turkestan (6).

The intensity of distillation of water in the soil during the winter may be increased by such agricultural tillage practices which favor a greater freezing of the soil.

During the second half of spring, summer and fall the following distribution of temperature may be observed in the upper layer of the soil and the layer with the constant temperature: the nearer the horizon is to the surface the higher is its temperature and vice versa. Since the soil moisture, except in the uppermost layer, is always greater than the maximum hygroscopicity, then the vapor pressure must be there at its maximum corresponding to the temperature. Therefore the vapor pressure during the summer is greater in the upper layers than in the lower ones, and because of that the water must move in the vapor form from top to the bottom. Down below that layer with the constant temperature the latter increases with the depth and in accordance with it the vapor pressure increases and at the border line of the layer with the constant temperature the second stream of water vapor is moving.

At the point where the vapors meet it is condensed and liquid water is formed giving rise to the first horizon of the ground waters.

It has been empirically established that in Loess steppe the first horizon of the ground waters runs almost parallel with the relief of the region. Since the horizon with the constant yearly temperature begins from where the influence of the sun on the thermal régime of the earth's crust ends, it is easy to explain why the relief of the first horizon of the ground waters repeats the relief of the region.

The findings of Nordenschild ground waters in the solid granites just in the layer of constant yearly temperature[1] appears to be in harmony with the point of view just developed. In those cases when the liquid water of the first horizon formed from the vapor cannot remain at the point of its formation and it is moving downward because of the forces of gravity it is possible that the water table of the ground waters may not correspond with the place of its formation.

It is worth while to note that in the formation of the ground waters by process of condensation it is important to recognize the place of formation and the location of the water table. The place of formation and location of the water table may or may not coincide, depending on the physical structure of the corresponding horizons of the earth's crust.

It has been noted already that in the earth's crust with an increase in depth, a constantly increasing temperature causes the water vapor to move from the lower to the upper layers. In places where the greater intensive movement of the vapor is inverted into a lower intensive movement, that is, where the inflow of water vapor to the given horizon is less than the outflow from the same horizon per unit time, an accumulation of liquid water must be observed.

This phenomenon is similar to the action of three distillation flasks connected in a series where the amount of water distilled over from the first into the second and from the second into the third is decreasing per unit of time. The change in intensity of movement of water vapor is primarily determined by the changes in the thermal gradient of the earth's crust. In those layers where the thermal gradient is lower the intensity of the movement of the vapor, all other conditions being equal, must be greater than in the layers with a higher thermal gradient.

At the border line where the layers with a lower thermal gradient are underlaid by layers with a higher thermal gradient liquid water must accumulate when the vapor is moving from below upwards, and this is the cause for the formation of ground waters of the second, third, etc. horizons.

In the zone of the eternal freezing where infiltration is impossible the second, third, etc. horizons of ground waters is formed in the manner just

[1] P. V. Ototszkii has called attention to it when he reviewed the work of the author in his paper Current Problems in Scientific Hydrology. Hydrological Review, 1915, No. 1.

described. In the temperate and southern latitudes it is hard to find a case which would illustrate strikingly the process of the formation of ground waters just described; still such cases are known. According to the observations of A. A. Kozuirev an alternation of fresh and salt water horizons may be observed infrequently in the tertiary deposits in the following order: first, horizon of water is strongly saline; second, fresh, and third, again saline. Apparently the second fresh horizon of ground waters could not have formed by infiltration from the waters of the first saline horizon of the ground waters. Kozuirev considers it incredible that the second horizon should at some points within a large area appear at the surface and the atmospheric precipitation penetrate the layer of the first water carrying horizon; the layers are deposited in great stretches almost horizontally. The case studied by Kozuirev illustrates strikingly the formation of ground waters by condensation of the water vapor moved from the depths of the ground.

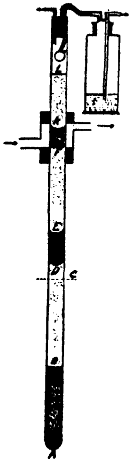

FIGURE 3.—A demonstration of the formation of ground waters by distillation of water vapor within the earth's crust

The process of the formation of ground waters by distillation of water vapor within the earth's crust may be illustrated experimentally. Into the lower portion of a glass tube (fig. 3) very moist sand is placed A B. On the top of it air-dry sand B L is placed to a height of 33 cm. The lower end of the tube A C is placed in a thermostat with a temperature of 40°; the upper portions C F and K L are kept at room temperature (15 to 18° C.); a portion of the tube F K was covered with a water-jacket through which cold water (9° C.) was passing through. Air saturated with water vapor at room temperature was passed over the sand in the upper portion of the tube. In such a manner there were four thermal zones in the tube and correspondingly four zones of different vapor pressures (maximum pressure at the given temperature): zone A C with a vapor pressure of 54.8 mm., zone C F and K L with a vapor pressure of 14.1 mm. (average from 12.7 to 15.4) and the zone F K with a pressure of 8.6 mm. Under such conditions of the vapor pressure the vapor must move from zone A C into zone C F with a difference in pressure of 40.7 mm.; from zone C F into zone F K at a difference of pressure in 5.5 mm. Therefore, the zone C F will obtain more water from zone A C as it will give up to zone F K, and at the border zone A C and C F, this surplus will condense into liquid water, forming a dark ring D E analogous to the second horizon of the ground waters. The vapor will move to zone F K from above and from below and here the second ring of liquid water will form analogous to the first horizon of ground waters. These rings of liquid water may be seen

not only with the naked eye but the accumulation of the water may be determined directly by determining the moisture content of the sand at those rings.

One of the characteristic peculiarities of the soil is the development of its inner surface, that is, the surface of the soil particles, and this causes the development of tremendous surface forces in the soil. In the life of the soil and ground waters these forces play an important rôle and their study deserves most careful attention of the hydrologist. Several phases of this problem were studied in the following manner.

Samples of the same soil with various moisture contents were brought in contact with each other by placing them in test tubes 15 cm. long and 2 cm. in diameter. The movement of the water was determined by the changes in moisture content of the adjoining layers. To exclude the changes in the moisture content of the soil due to the movement of water in the form of vapor, one set of tubes was arranged so that the layers of the soil with the various moisture contents were adjoining each other directly, while in the other series of tubes the various layers were separated by a series of metallic sieves. The walls of the tubes with sieves were treated with paraffin so that no water should move along the walls because of the forces due to the wettening of the walls. In the tubes with the sieves the water vapor W D could freely move from one layer of soil into the other; on the other hand in the tubes without sieves the liquid water could move simultaneously in the form of a liquid F W and as vapor W D. Subtracting from the latter determinations the first ones (F W+W D)−W D one obtains the movement of water in the liquid phase F W. In order to exclude the movement of water under the influence of gravity, the wettest layer was located at the bottom, the driest at the top.

Experiments of that type have shown that if the soil moisture is less than its maximum hygroscopicity, then the water may move in the soil only in the form of vapor and not as a liquid (8) and besides the vapor is moving from a more moist layer into a less moist layer (see also paragraph 2). The average data from 14 observations on chernozem with a maximum hygroscopicity of 7.66 illustrate this. The experiment was continued for 18 days at a temperature of 32.3°; the moisture in the beginning of the experiment was 6.23 per cent in the lower layer and 2.43 per cent in the upper layer. The moisture content of the upper layer after the experiment was: in the tubes without the sieves 3.70 per cent, in the tubes with the sieves 3.68 per cent. Experiments of that nature but with soils having a moisture content greater than its maximum hygroscopicity have shown that when two layers of soil of various moisture contents come in contact, the water is moving as a liquid from the more moist layer of the soil into the layer of less moisture (9). One of the experiments illustrates this. An orchard soil with a maximum hygroscopicity

of 8.97 per cent was used. The time period of the experiment was 16 days at a temperature of 30.1° C. The average moisture content of the soil was before the experiment 11.43 per cent in the dry layer and 16.63 per cent in the wet layer. At the end of the experiment in the dry layer without sieves the moisture content was 13.83 per cent and with the sieves 12.57 per cent. Thus 1.26 per cent of liquid water moved. We see then that the maximum hygroscopicity is the limit where on one side of which the water is moving only as a gas (hygroscopic form of soil moisture) and on the other side it is moving as a liquid. This circumstance is especially interesting because as it has been shown before (paragraph 1) the relative humidity of the air in the soil with a moisture content greater than its maximum hygroscopicity is equal to 100, while in soils with a moisture content lower than its maximum hygroscopicity the relative humidity of the soil air is less than 100 per cent (paragraph 2). The phenomena just noted may be genetically related if we should agree to the fundamental ideas of the theory of hygroscopicity as presented by Rodewald (9), according to whom the maximum hygroscopicity corresponds to that condition of moisture when the particles of the hygroscopic substances are surrounded with a water film composed of one layer of water molecules (see fig. 6). Constructing a model corresponding to the view of Rodewald it may easily be seen that for the case when the soil moisture is less than its maximum hygroscopicity, the water film surrounding the soil particles must have a mosaic structure and in between interspaces of the particles covered with a mono-molecular water film, there will be waterless regions of the surface of soil particles. Apparently these waterless regions will be more the less the hygroscopicity of the soil is at a given moment (fig. 6).

Turning our attention to the relative humidity of soil air we see that at maximum hygroscopicity it is equal to 100 per cent. This signifies that between the evaporation of the water film which entirely envelopes the soil particles and the humidity of the soil air there is the same kind of an equilibrium as in an enclosed volume over a free water surface. Since the evaporation of the mono-molecular film takes place on the one hand under the influence of the cohesion between the molecules of water on the soil particles and on the other hand under the influence of temperature, it is clear that these forces at a given temperature remain constant at all stages of hygroscopic moisture. Consequently, if at equilibrium between the evaporation (tearing away of molecules of water from soil particles) and the reverse process—condensation of molecules of water on the soil particles—the maximum hygroscopicity is expressed by 100 of the relative humidity, then any other condition of hygroscopicity when the water film does not envelop entirely the soil particles must be expressed by a value less than 100. The experiment by the author confirmed this conception (p. 2). An examination of the Rodewald model shows that the hygro-

scopic moisture represents the water vapor which is held by the soil because of the forces of cohesion but not water as a liquid. Experiments by the author on the other hand show that the hygroscopic form of moisture does not move as a liquid but only as a gas (p. 8).

The theory of Rodewald was based experimentally on the study of the heat of wetting which takes place at the absorption of water by hygroscopic substances. Although this phenomenon is of an entirely different order than what has been studied by the author (the movement of water and the relation between the relative humidity of the soil air and the water content in the soil), still it could be explained on the basis of the Rodewald theory and in this way the theory is corroborated.

Thus the maximum hygroscopicity of a soil is that lower limit of moisture at which there is no possibility for liquid water to move under the influence of molecular forces. But where will be correspondingly higher limit of moisture, that is, that limit where the influence of the molecular forces ceases because of the excess of soil moisture? Apparently this limit must correspond to that condition of the soil moisture at which the influence of the molecular force between the soil particles and the water ceases, or, in other words, this limit must be determined by the maximum wetness of the soil. A small excess of water above the limit just referred to cannot be held by the soil and such water must fall because of the forces of gravity. In order to approach experimentally the determination of the limit we are interested in we shall look first into the following phenomenon.

Let us pour into a long capillary tube made of a substance which is wetted by water a considerable amount of water through its upper end. The following will take place: a portion of the water poured in will flow out from the tube, another portion will remain in the tube, filling up its lower end, and finally a small portion of water will be consumed for the wetting of the walls of the tube. The amount of water utilized for wetting the walls depends upon the substance the tube is made out of and is a real expression of those molecular forces of cohesion which are apparent between the water particles and the substance of the tube. In the soil we encounter in reality the same conditions as in the capillary tube and consequently to determine the maximum wetness of the soils it is important to study their moistures in the upper portion of long soil columns. A tube of 4 to 5 cm. in diameter, 1 to 3 m. long, is being filled with soil. It is easier to work with sand or sandy loam soils because clay soils require a long time and longer tubes (8–10 m.). At the bottom the soil is held up in the tube by gauze; on the top water is flowing under constant pressure (2 cm.). When saturation and run-off of water in the tube reaches its maximum the inflow of water ceases. Still the run-off of water continues and lasts so much longer and so much more water is running out the higher the layer of the soil is. When the run-off finally ceases the segments of the tube are taken apart and the soil moisture in each segment

(10 cm. long) is determined. The result of one such experiment with medium-grained sand is given in Table 11. The height of the tube with the sand was 150 cm.

TABLE 11.—Moisture in each 10 cm. segment when run off

Height of sample in the column	Moisture in the sand	Height of sample in the column	Moisture in the sand
cm.	per cent	cm.	per cent
150	1.69	70	1.72
140	1.81	60	1.91
130	1.79	50	2.07
120	1.80	40	3.11
110	1.85	30	6.21
100	1.69	20	14.12
90	2.01	10	15.38
80	1.84	0–1	16.24

The experiment shows that in the sand column beginning with 40 cm. a uniform moisture content prevails which is in accord with the scheme of the distribution of water in a capillary tube. It may thus be inferred that the moisture of the sand corresponding to its maximum wetness is equal to 1.81 per cent (average from determinations in the column from 60–150 cm.). This may be looked upon as the upper limit of the influence of molecular forces. *The ability of soils to retain certain amounts of moisture by the forces of molecular cohesion the author calls "molecular moisture holding capacity of the soils"* (*10*).

The maximum molecular moisture holding capacity may be determined by centrifuging a water soaked soil. In fact the investigations of Plateau, Drude, Quinke, Vincent and others have shown that the sphere of influence of the molecular forces is very small (0.006–0.056 μ) and the surface tension caused by these forces reaches tremendous values—for water for instance, up to 10,700 atmospheres according to the investigations of Von der Waals. Comprising such a minute value of the sphere of action of molecular force on the one hand and those great forces which they cause on the other hand, one must realize the tremendous value of the gradient of molecular forces. One may therefore assume that water held by the soil particles has a very sharply defined limit. On the basis of these considerations it was suggested that by utilizing strong centrifuging it will be possible to speed up the run-off of excessive moisture from the soil and obtain the moisture corresponding to the maximum molecular moisture holding capacity. For experiments with centrifuging a centrifuge was used which developed a speed equal to 400 G (G is the speed of the forces of gravity). Moist sand in a layer of 3 cm. was placed in tubes and four such tubes were subjected simultaneously to centrifuging for a period of 1

hour. After centrifuging the amount of moisture left in the sand was determined eliminating 2 to 3 mm. of the dried outer layer of the sand. Experiments of this kind have shown that whatever the moisture of the sand was before centrifuging, it was equal to its maximum molecular moisture holding capacity after centrifying and it corresponded to the amount determined by the method of high columns. The figures in Table 12 are a typical example.

TABLE 12.—Moisture content after centrifuging

Number of experiment	Moisture content after centrifuging
	per cent
1	1.78
2	2.01
3	1.96
4	1.88
Average	1.91

The maximum molecular moisture holding capacity of the same sand as determined by the method of high columns equalled 1.81 per cent which corresponds very nicely with the value obtained by centrifuging. If the sand taken from the upper portion of the high sand column is centrifuged, no water is forced out. Thus 1 G and 400 G produce the same effect which indicates the difference of the limit which determines the water held by molecular forces which the author calls film water in distinction from the following form of water which runs off under the influence of gravity. It is natural to expect that the intensity of the movement of film water (within the limits of maximum hygroscopicity to maximum molecular moisture holding capacity) in moving from one layer into another is not dependent on the forces of gravity. Preliminary experiments did not confirm this supposition. The experiments were carried out as follows; a moist layer of soil was placed in a test tube between two equally dried layers (fig. 4). After 2 to 3 weeks the increase in moisture in the dry layers was determined and every time it has been found that the moisture content of the lower dry layer was somewhat greater than the moisture content of the upper dry layer. This could be interpreted that the film water did move under the influence of gravity. However, a more detailed analysis of the conditions of the experiment shows that the relation of the lower dry layer C to the wet layer A immediately above it is not identical to the relation of the upper dry layer B to the same wet layer A lying just beneath it. In filling up the tubes with soil it is necessary for the purpose of more uniform compactness to pour the soil into the tubes in small fractions and as far as possible compact these portions by pressing.

Under such conditions the layers of the soil subject to direct influence of the compacting force are compacted more than those layers which are lying below.

The degree of compactness is shown by the horizontal line in Fig. 4-a and b. An analysis of the figure shows that the dry compacted layer C is in contact with the moist, loosely put together layer A; at the same time the loosely compacted dry layer B from the top is in contact with a compacted moist layer A.

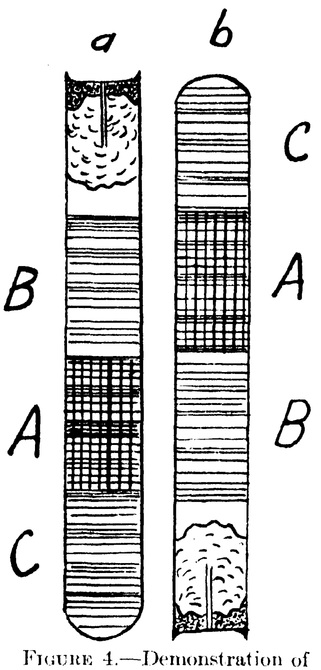

FIGURE 4.—Demonstration of the movement of film water irrespective of the forces of gravity. (See text for demonstration)

Because of the various conditions at the point of contact of layers A and B on the one hand and A and C on the other hand, it was assumed that the excess of water moving into layer C is due to these differences and not to the forces of gravity. In order to solve this question one-half of the tubes were inverted (fig. 4-b) and then it turned out that in the series of tubes (b) the water moved more into the same layer C although under such conditions it was lying above layer A.

The experiment illustrates the following: the moisture of the moist layer before the experiment was 15.91 per cent (an average of 20 observations); the moisture content of the dry layer before the experiment was 9.54 per cent (average of 40 observations). The time period of experiment was 25 days. The moisture content of the dry layers after the experiment is given in per cent (average of 20 observations).

Group A		Group B	
Layer B (above A)	Layer C (below A)	Layer B (below A)	Layer C (above A)
11.45	11.81	11.44	11.89

Thus the film water is moving from more moist layers into layers with less moisture and the intensity of the movement does not depend upon the forces of gravity (11).

Besides a comparison of the experiments, series (a) and (b) (fig. 4), shows that compacting the dry layer is inducive to a higher moistening when in contact with a loose, moist layer and vice versa.

If the soil has a moisture content greater than its maximum molecular moisture holding capacity, then the excess of water not held by molecular

forces being under stress because of the forces of gravity must move downward unless, for one or the other reason, it will encounter a counterforce and stop in the soil or at the water table where it will follow the same route as the rest of the water from the water table. The following observation will give us an idea of the several properties of this form of water which we shall call gravitational water. Let us take six pair of tubes 10 to 100 cm. high. Let us fill them up with sand (see Table 13) and for 3 hours filter water through them under pressure of a 2 cm. column of water. After that the inflow of water from above is stopped

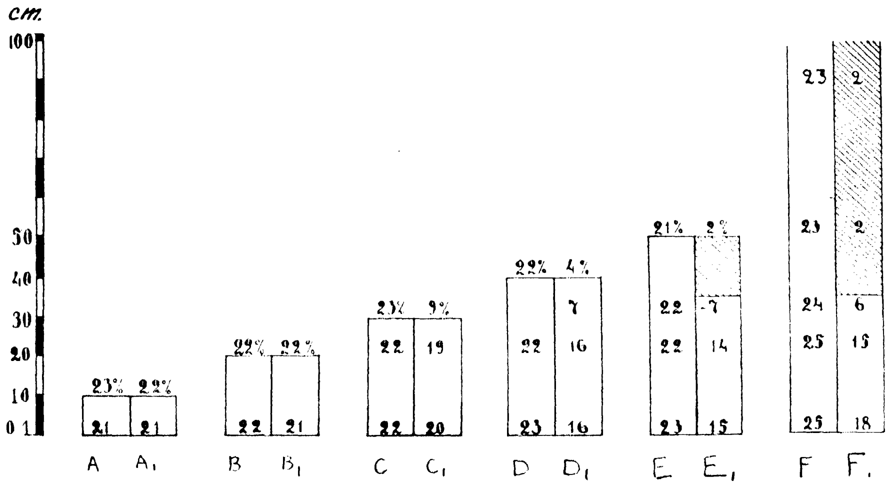

FIGURE 5.—The changes in water holding capacity of any type of soil (sand in this case) in relation to the depth

The unshaded portion indicates gravitational water. The shaded color portion indicates film water corresponding to the maximum molecular moisture holding capacity.

A–E represent the moisture content of the sand during the downward filtration of the water from above.

A_1 E_1 represent the water holding capacity of sand after the excess of water has run off when filtration was discontinued.

and as soon as the surface of the column is free from water, samples are taken from the first series of tubes A, B, C, D, E, F and the moisture determined. The tubes of the second series A_1, B_1, C_1, D_1, E_1, F_1 were left until no more moisture was dripping from them and then the moisture content determined. The results of one of such series of experiments are given in the following Table 13 (see also fig. 5).

The experiment shows that at the moment of filtration the moisture content of the sand in the short and long tubes is almost the same and is equal to 21 to 23 per cent. As soon as the inflow of water into these tubes is stopped and after the excess of moisture has run off, the distribution of the water in the tubes at various heights varies (Tubes A_1 to F_1): in the

short tube at 10 cm. the run-off is not observed as soon as the surface of the sand is free from excess of water and for that reason the moisture of the sand in Tubes A and A_1 is the same. In the 20 cm. tube a run-off of several drops was noticed and the degree of moisture in the Tubes B and B_1 is also practically the same. In Tube C_1 at 30 cm. high a small run-off of water may be observed and therefore in its upper portion the moisture content of the sand decreases from 21.4 per cent (Tube C) to 12.8 per cent (Tube C_1). In Tube D_1 and E_1 (40 and 50 cm.) the run-off of water is even greater than in C and the moisture content of the upper layer of the sand drops to 2.3 per cent (Tube E_1).

TABLE 13.—Moisture in sand when surface is free of water and when run-off ceased

Height of sand	Moisture content of sand in per cent											
	A	A_1	B	B_1	C	C_1	D	D_1	E	E_1	F	F_1
cm.												
100											23.1	1.9
90											23.3	2.1
80											23.0	2.0
70											23.1	2.1
60											23.6	2.5
50									22.3	2.3	23.2	2.2
40							22.4	3.0	21.0	3.5	24.1	2.2
30					21.4	12.8	22.1	7.5	21.7	7.9	24.3	6.0
20			22.2	21.5	22.4	18.5	22.4	16.4	23.4	15.1	24.7	13.7
10	22.4	22.1	21.1	20.8	21.7	21.3	21.9	18.0	23.4	14.5	25.4	15.7
0–1	21.1	20.7	21.6	20.3	21.9	20.3	22.4	18.2	23.5	15.3	24.5	15.3

In Tube F_1 the run-off continued for 3½ days during which time about 300 cc. of water was collected. In its distribution the formation of a layer with a constant moisture content beginning with a height of 40 cm. may be observed. This layer as has been shown above has a maximum molecular moisture holding capacity and its moisture content is controlled by the molecular attraction of the water by the soil particles. An increase of the sand columns to 2, 3 and 4 m. does not change the phenomenon observed in Tube F_1; the moist layer located at the bottom of the tube remains unchanged and only the layer with a constant maximum molecular moisture holding capacity becomes greater and greater. The moist layer formed in all tubes of series A_1 to F_1 is by its nature analogous to the water suspended in a capillary tube the lower end of which is freely suspended in the air (fig. 7-A). The analogy will be complete if in place of one capillary tube we should imagine a bundle of capillary tubes of various diameters. Without going into details with this analogy we shall turn our attention to the analysis of more interesting phenomena.

If we should pour 2 to 4 drops of water on the sand in Tube A_1, immediately the same amount of water will drip from the bottom of the tube.

TABLE 14.—Quantitative relation of added water to run-off

						Total
Water was added, in g.	0.53	4.72	2.33	4.25	0.91	12.74
Water dripped, in g.	0.50	4.71	2.37	4.19	0.89	12.66

In Tubes C_1 to F_1 where the moisture content of the upper layers of sand begins to decrease, especially where the layer with a constant maximum molecular moisture holding capacity appears, such a dripping may also be observed but it differs considerably; it begins only upon the expiration of a short period of time after the water has been added. This period is greater the longer is the layer with a maximum molecular moisture holding capacity. To clear up the reason for such a difference the following experiments were conducted: Into Tubes A to F_1 a solution of LiCl 0.00001 per cent concentration was poured. After the addition of such a solution in Tube A_1 a movement of the water and dripping was noted but no lithium could be detected. (The lithium was examined spectroscopically.) This shows that in the sand that has a moisture greater than its maximum molecular moisture holding capacity the water added changes the conditions of equilibrium; this change is transmitted hydrostatically to the lower layer where because of the disturbed conditions of equilibrium a dripping is observed and equilibrium again established. If the solution of lithium chloride should be added to Tube F_1 and to the others where a layer with a maximum molecular moisture holding capacity is greater (2 to 3 m.), then upon the expiration of a period of time a dripping of water will begin, but the water will run down without lithium. If at the moment the first drop of water comes off, a determination should be made as to the location of the lithium, then in all tubes no matter how long they would be and no matter how long a period has elapsed after the addition of the lithium chloride, lithium will be observed there where the layer of gravitational water begins. Thus the added water (the solution of lithium chloride) penetrates the layer of sand with a maximum molecular moisture holding capacity as such and not by the forces of hydrostatic pressure with a consequent disturbance of the equilibrium in the lower moist layer of sand. Reaching the upper limit of this layer of gravitational water, by transmitting the pressure water is squeezed out from the lower end of the tube and we may observe a run-off of water without lithium. Experiments of such a type give a new characteristic of the film form of water and in it the hydrostatic pressure is not transmitted (12). Film water must be considered in a way as a solid system. This does not conflict with the above established point that film water is moving as a liquid for even the solid phase of water (ice) is also moving (glaciers).

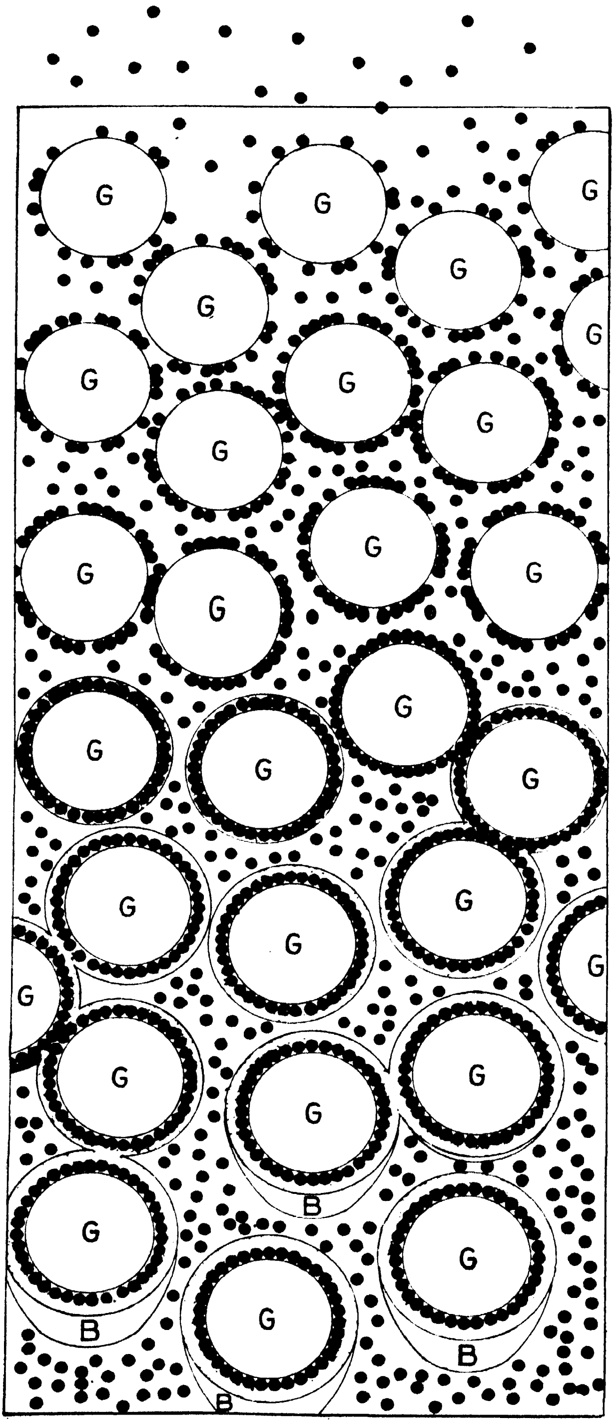

FIGURE 6.—Forms of soil water at temperatures higher than 0° C.

1. The black circles on top represent water vapor molecules; first form of soil water, vapor water.

2. Black circles located over soil particles (large circles (G)) are water molecules; second form of soil water, hygroscopic.

3. Outer circles not lettered represent film water, the third form of soil water.

4. Circles marked B represent gravitational water, the fourth form of soil water. (a) Capillary water ascending through the soil mass from the ground waters (analogous to the water in a capillary tube immersed in water; see Fig. 7-B). (b) Suspended water; water that cannot drop any further because of certain physical phenomena (analogous to suspended water in the capillary tube; see Fig. 7-A).

Apparently the conclusions of the just noted condition is a very slow movement of the film water in a homogeneous soil mass as has been shown by special experiments not reported here because of their simplicity. On the basis of all the experiments cited the author considers the following forms of water in soils and ground:

1. *Vapor phase.*—Water as a gas; it is moving from a gradient of higher vapor pressure to a gradient of lower vapor pressure. The relationships between the vapor pressure and soil moisture have been expounded in paragraphs 1, 2, 3 (see fig. 6).

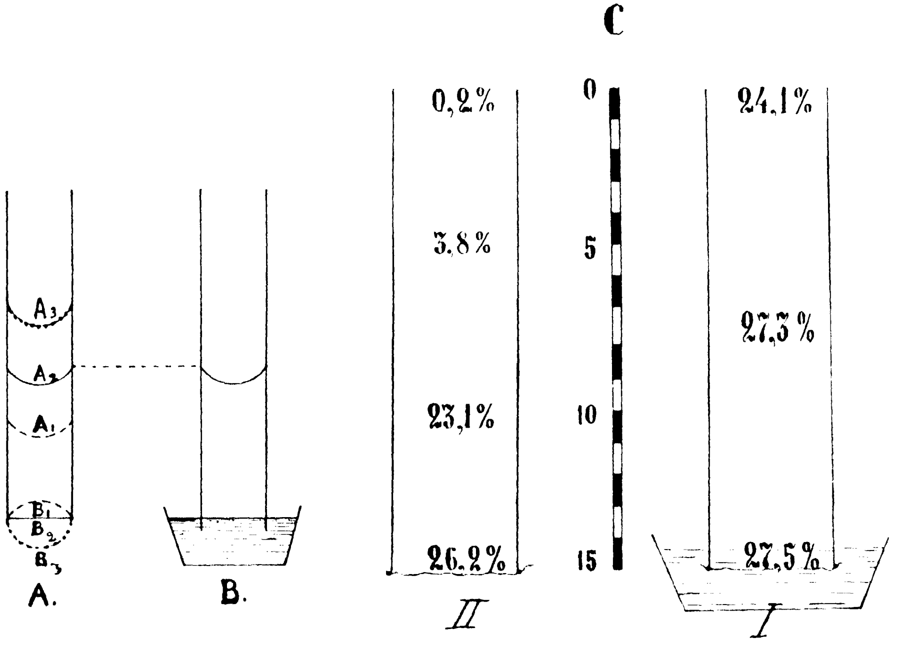

FIGURE 7.—An illustration of the absence of capillary rise in soils with suspended water (having no direct connection with the ground water).

A. Capillary tube with end not immersed in water.

B. Capillary tube with end immersed in water.

C-I. The distribution of water in a sand column with its lower end immersed in water and the upper end of which has been heated for 8 hours with a Bunsen flame.

C-II. The distribution of water in a sand column with the same moisture content as in I, but with its lower end not immersed in water. This was also heated for 8 hours as I; the condition shown is 2 days after the heating was discontinued.

2. *Hygroscopic water.*—Molecules of water vapor held on the surface of soil particles by the forces of cohesion. The process of change from gaseous molecules of water into hygroscopic condition is accompanied by a release of heat (Rodewald, Mitscherlich and others). This form of water does not move as a liquid but is capable of moving from more moist layers into less moist layers in the form of vapor (see fig. 6).

3. *Film water.*—Water under the influence of the molecular forces of cohesion between the soil particles and the water. It is moving very slowly as a liquid from more moist layers into less moist layers (from places with a thicker film to places with a thinner film). The intensity of this movement does not depend on gravity. No hydrostatic pressure is developed by film water (see fig. 6).

4. *Gravitational water.*—Water moving under the influence of the forces of gravity (see fig. 6). In such a form of water hydrostatic pressure is apparent. The speed of the movement of this form of water as compared with that of the film water is great. In the gravitational form of water it is expedient to distinguish the following variations:

(a) *Capillary water.*—Filling up the capillaries through which the moistures from the ground waters rise. When the height of the water in the capillaries is lowered (by evaporation and utilization by plants) a quick rise takes place analogous to the rise of water in a capillary tube, the end of which is immersed in the water (see fig. 7-B).

(b) *Suspended water.*—When the gravitational water has no connection with the ground waters as if it was suspended in the soil or ground. This case is analogous to a condition of water in a capillary tube the end of which is not immersed in water but is hanging freely in the air (see fig. 7-A). When evaporated from the surface the lower layers of such water cannot be drawn up to the surface (see fig. 7-C).

(c) *Gravitational water in a condition of falling.*—Besides these four forms of water which have been to a certain extent studied by the author, it is necessary to consider a fifth form, namely, the *solid phase.* A sixth form of water is the *water of crystallization* and a seventh form is the *chemically combined constitutional water.*

We shall briefly note the results caused by the study of the properties of the liquid phase of water. The relation between the maximum molecular moisture holding capacity as well as the maximum hygroscopicity and the size of the soil particles points to the fact that the properties described are more sharply defined, the finer the soil is and vice versa. For that reason while the maximum molecular moisture holding capacity of sand is about 2 per cent, for loess it was 15.98 per cent (average of 10 determinations). At the surface between the soil and the air specific forces are developed which retain the gravitational water in the lower portions of high columns. An analogous phenomenon is also observed at the upper end of the tubes, but it is not so sharply defined in sands but markedly visible in clays. Table 15 illustrates this.

From the standpoint just presented it is clear that cracks in soils greatly modify the moisture holding capacity of the homogeneous soil. This may be demonstrated imagining that Tube F_1 (see Table 13) was cut up into individual segments 10 cm. long. In each one of these short tubes the moisture content would be equal to that in Tube A_1 (21 to 22 per cent)

TABLE 15.—Moisture holding capacity of soil

Height of loess in tubes in cm.	20	50	100	200	300
Moisture content of loess in the upper portion in per cent	35.32	32.35	30.27	28.36	26.50
Moisture content of loess 10 cm. below the surface	29.72	27.44	25.41	24.00	21.41

and the total moisture content of the entire Tube F_1 would have increased sharply. The cracking of soil under natural conditions after rains creates, therefore, a temporary condition of excess moisture in the soil, since the moisture holding capacity of the separate lumps of soil is greater than the moisture holding capacity of the entire mass. The same thing holds true when a soil is plowed up. When the individual lumps of soil combine again into one mass because of their swelling due to an excess of moisture, the moisture holding capacity of the lumps must of necessity decrease and the excess of water run off. Thus a soil in dry regions may experience an excess of moisture because of the cracks followed later by strong leaching.

Cracks through the entire parent material, because of the forces developed at the surface of the system parent material-air play the rôle of an impermeable horizon. When a fine-grained parent material is underlaid by a coarse-grained parent material a similar phenomenon is exhibited. The following Table 16 shows the moisture of a soil after the excess moisture has run off.

At a height of 100 to 150 cm. the moisture content of loess underlaid by loess is equal to 25 to 26.3 per cent (Tube 1); at the same height the moisture content of loess underlaid by sand is equal to 27.2 to 33.6 per cent (Tube 2). At the border line of fine sand and coarse sand (51–50 cm. high, Tube 2) whereby the coarse sand is below the fine sand, an increase in the moisture content is also observed (5.3 per cent). If the coarse-grained material is underlaid by a fine-grained material then no increase in moisture may be observed in the coarse-grained layer. This is very distinctly seen at the border of the coarse-grained and fine-grained sand (Tube 3, 151–150 cm.); also at the border of the fine-grained sand and loess (Tube 3, 101–100 cm.).

The experiment shows that in soils formed from heterogeneous material the water at the moment of its equilibrium distributes itself differently than in soils with a homogeneous structure; if the large grained mass is below the finer gra'ned mass then more water is retained in the fine grained mass than if it would be underlaid by material of the same type.

This observation points to a new method of amelioration; the percolating waters may be partially held back by underlaying the soil with large grained sand in layers of 5 cm. thick a: intervals of 1 to 1½ m. The author does not desire to discuss this proposition from the economic point of view as this phase requires further study.

TABLE 16.—Moisture in various soils after excess moisture runs off

Height	Tube 1		Tube 2		Tube 3	
	Parent material	Moisture	Parent material	Moisture	Parent material	Moisture
cm.		per cent		per cent		per cent
200	Loess	28.4	Chernozem	39.2	Coarse sand	2.4
190	Do	24.0	Do	36.2	Do	2.1
180	Do	24.9	Do	36.2	Do	2.1
170	Do	25.6	Do	33.6	Do	1.8
160	Do	24.8	Do	34.1	Do	1.9
151–150	Do	25.0	Do	35.4	Do	1.8
150–149	Do		Loess	29.0	Fine sand	2.6
140	Do	25.7	Do	27.6	Do	2.5
130	Do	26.1	Do	28.4	Do	2.4
120	Do	26.3	Do	28.1	Do	2.4
110	Do	25.1	Do	27.2	Do	2.4
101–100	Do	26.0	Do	33.6	Do	2.4
100–99	Do		Fine sand	3.0	Loess	28.8
90	Do	26.7	Do	2.7	Do	28.9
80	Do	26.3	Do	2.7	Do	28.6
70	Do	24.4	Do	2.7	Do	29.1
60	Do	24.3	Do	3.5	Do	29.5
51–50	Do	25.4	Do	5.3	Do	30.2
50–49	Do		Coarse sand	2.9	Chernozem	38.8
40	Do	25.9	Do	3.2	Do	43.5
30	Do	26.8	Do	4.3	Do	41.8
20	Do	27.8	Do	10.6	Do	41.9
10	Do	29.7	Do	11.1	Do	47.6
0–1	Do	36.4	Do	14.7	Do	47.6

The phenomenon just discussed should be considered also when soils are characterized by their physical attributes, since the various combinations of hydrological conditions in the soil profile may explain a whole series of peculiarities and properties of this or the other soil type.

The distribution of moisture in columns alternating with layers of different mechanical composition gives another interesting illustration as to how the distribution of water by horizons depends upon mechanical composition of the soil. The water in Tube 3 (Table 16) is in a state of equilibrium and still the moisture of the various horizons fluctuated about 2, 2.5, 29 and 44 per cent; these differences correspond with the mechanical composition of the various horizons. The change in moisture holding capacity of the soil in relation to the mutual location of the horizon must be considered in building a road-bed since the moisture hold ng capacity of the ground determines in a way the technical strength of it.

It has been noted already that in a uniform soil the movement of film water from the moist layers into the dry ones takes place very slowly. A

different picture may be observed if we place together several layers of different mechanical composition with a different inner surface of the particles; under such conditions the water moves rapidly from the layer with a relatively lower inner surface of soil particles towards the finely grained layer. The following observation illustrates this.

Odessa chernozem and sand were placed side by side. The experiment was continued for 27 hours at a temperature of 26.5°. In the first experiment (average of 10 observations) the sand was located over the chernozem. In the second experiment (average of 10 observations) the sand was located under the chernozem. Table 17 gives results.

TABLE 17.—Movement of film water in layers of soil of different mechanical composition

Moisture in per cent			
Before experiment		After experiment	
Chernozem	Sand	Chernozem	Sand
22.37	9.41	28.74	3.83
11.23	20.68	31.34	4.01

The observations just given in a way explain the variations in the moisture content of the horizon of a different mechanical composition at the moment of moisture equilibrium in the column after the excess of the water has run off.

The intensity of the movement of the liquid phase of water depends on temperature, decreasing with a decrease in temperature; this may be due to an increase of friction. The following example illustrates it. A moist layer of chernozem (19.41 per cent) was placed into a tube between two dry layers (moisture content 11.29). Ten tubes were placed in a thermostat at 30.2°; another 10 in a thermostat at 12.5°. The experiment was continued for 28 days. Table 18 gives the moisture content of the dry layers of the soil after the experiment.

TABLE 18.—Influence of temperature upon movement of liquid phase

Moisture at 30.2°		Moisture at 12.5°	
Upper layer	Lower layer	Upper layer	Lower layer
per cent	per cent	per cent	per cent
13.50	14.06	13.08	13.63

At 30.2°, 0.42 per cent more moisture moved into the dry layers than at 12.5° C. Since at 12.5°, 2.07 per cent of moisture moved on the average up and down, then the intensity of the movement of the water at 30.2° is

greater than at 12.5° with 20.3 per cent (if we take 2.07 per cent as 100). From this standpoint the methods of tillage which decrease the temperature of the soil become interesting. For the southern regions this is especially important for the following reasons. In that region the soil gravitational moisture is not in direct contact with the capillary water which rises from the ground waters. These waters are suspended and are analogous to the water in a capillary the end of which is not immersed in water but is suspended in the air (fig. 7-A). We shall examine now the conditions of equilibrium of the water in such a case. It will take place whenever the surface pressure of the water at the upper meniscus is equal to a similar pressure at the lower meniscus. Three cases are possible:

$$K-\frac{2a}{R}+P_1=K-\frac{2a}{R_1}.\text{[1]} \quad (1)$$

In this case the lower meniscus B_1 has a convex shape. Increasing the height of the water column in the capillary increases P_1 and the lower meniscus attains finally a horizontal position B_2; the equilibrium is determined by the following equation:

$$K-\frac{2a}{R}+P_2=K. \quad (2)$$

Increasing still further the height of the column in the capillary the conditions of equilibrium are determined by the following equation: the lower meniscus B_3 will take on a concave form.

$$K-\frac{2a}{R}+P_3=K-\frac{2a}{R_3}. \quad (3)$$

In this equation K is the normal surface pressure of the free horizontal water surface, a = surface tension of water, A_1, A_2, A_3 = the upper meniscus in the first, second and third cases; R is the radius of the curvature of the upper meniscus A_1, A_2, A_3; R_1 is the radius of the curvature of the lower meniscus B_1; R_3 is the radius of the curvature of the lower meniscus B_3; $R > R_1$; P_1, P_2 and P_3 is the hydrostatic pressure in the capillary of the meniscus B_1, B_2, B_3; $P_3 > P_2 > P_1$.

Examining the conditions of equilibrium from the third (3) to the first (1) we come to the conclusion that the decrease in height of the water in the capillary (from meniscus A_3 to meniscus A_1) may cause changes in the curvature and shape of the lower meniscus (from B_3 to B_1); it cannot, however, influence the movement of the water to the upper end of the capillary. The same phenomenon ought to take place in the soils of the southern regions whenever they contain suspended gravitational water. Apparently in such cases the loss of water by the upper layers of soil cannot be compensated by the capil'ary movement of water from below and, therefore, the drying of the soil must take place in succession from the

[1] The Laplace equation.

top downward (we have in mind here only the hydrological conditions and not biological such as the drying out of soils under the influence of roots). In the soils of the northern regions, where there is a direct connection between the water table and the capillaries, the expenditure of water by the upper layers of the soil may be made up by the capillary rise as it is generally accepted. In this case we have something analogous to a capillary the lower end of which is immersed in water; the equation for the capillary rise attains the following form:

$$K - \frac{2a}{R} + P_2 = K. \quad (4)$$

Since on the left and the right side of the equation all the factors besides P_2 are constant, it is apparent that also P_2 must be a constant; in other words, increasing P_2 by evaporation, etc. its significance must be compensated at the expense of the normal surface pressure of the free water K at the right hand side of the equation.

Experiments confirm these theoretical considerations (fig. 7-C). Wide flat tubes are filled with sand and completely saturated with water. The lower end of Tube 1 is immersed in water. The second tube is suspended in the air. The moisture content of the sand in the upper layer (0–1 cm.) of the first tube was 24.6 and the second 25.1. For a period of 8 hours a horizontal flame from a Bunsen burner was kept over the two tubes at a distance of 2 cm. from the surface of the sand. When the heating was completed the surface of the sand in Tube 1 had a moisture content of 23.8 per cent. In Tube 2 it was apparently dry. The tubes were left under a bell jar at room temperature for 2 days in order that the water lost by evaporation should be made up by the capillary rise of the water. Determinations of the moisture content of the sand at different layers after 2 days have shown that the moisture content in Tube 1 was 24.1 per cent at a depth of 0 to 1 cm., 27.3 per cent at a depth of 5 to 6 cm. At the same time the amount of moisture in the sand in Tube 2 was as shown in Table 19.

TABLE 19.—Moisture in Tube 2

	cm.	per cent
At a depth of	0–0.5	0.2
Do	0.5–1.0	3.8
Do	2.5–3.0	7.5
Do	6.5–7.0	9.9
Do	9.5–10.0	23.1
Do	14–15	26.2

The experiment shows that where the end of the sand capillaries was immersed in water notwithstanding the strong heating over the surface of the sand, the sand remained all the time with the greatest (capillary)

amount of moisture while in case 2 where the water was suspended the movement of the water from below upwards was not observed notwithstanding that at a depth of 9 cm. the sand had almost the greatest moisture content. It is worth while to notice that the water in the sand the lower end of which was immersed in water has risen along the capillaries up to the 20 cm. mark during a day.

The inability of gravitational water which is found in the soil of the southern regions in a suspended condition because of the capillary movement on one hand and the very slow movement of film water on the other hand increases the significance of the movement of water in these soils in the form of vapor.

From this point of view the temperature and the heat of conductivity of soils are of great interest. The movement of water vapor from the atmosphere into the soil and vice versa as has been explained previously depends in a great measure on the temperature of the soil. The lower the temperature of the soil the more energetic is the process of condensation and the less will be expressed the evaporation from the upper horizon of the soil (to the atmosphere as well as to the lower lying horizon of the soil). Under similar conditions the temperature of the soil may be decreased by decreasing the heat conductivity of the surface layer of the soil (Haberlandt, A. von Litrow, Wagner, Mamontov and others).

According to the observations of King (Wisconsin, U. S.) and Tolskii, Russia, the mellowing of the surface layer of the soil under natural conditions decreases the temperature of the soil up to 2 per cent; in the experiment of Tolskii at a depth of 5 cm. on an undisturbed plot the temperature was 24.3°; on mellow soil 22.4°. Figuring that the moisture of the soil has exceeded the maximum hygroscopicity and that the absolute humidity of the atmosphere was 12 mm. (the usual humidity in the summertime in the steppe), the difference in vapor pressure between the atmosphere and the soil was as follows:

On the undisturbed soil	10.6 mm.	(22.6–12)
On the mulched soil	8.1 mm.	(20.1–12)

Taking for a mulched soil the difference in vapor pressure between the soil and the atmosphere as a 100 per cent we shall find that for the undisturbed soil it is equal to 131 per cent. This will explain why all the methods which decrease the heat conductivity of the soil (mulching the upper layer, covering the soil with sawdust, etc.) decrease evaporation and conserve the moisture in the soil. We shall, in conclusion, examine the problem of the liquid phase of water and the formation of ground waters.

It has been shown that the movement of the water vapor alone is sufficient for the formation of ground waters. It would, however, be erroneous to think the liquid phase of water does not participate in the formation of ground waters.

Historically it happened so that science has turned its attention in connection with the study of the ground waters to the view of the Roman, Mark Vitruvi Polia. He assumed that the soil as well as the ground water comes from the atmospheric precipitation. After Mariott (1686–1717) this point of view was strengthened and the infiltration theory was generally accepted until recent times. However, in 1877 the German engineer, Otto Volger (10, 21) made very strenuous objections against the accepted view that "alles wasser welches in der Erde ist rührt vom Regenwasser." He presents his idea: "Kein wasser welches in der Erde ist rührt vom Regenwasser." Volger based his contention on a great number of observations on grounds in nature which always remained dry. Volger assumed, therefore, that the moisture holding capacity of soils is so great that all the water of the atmosphere is caught and retained by the upper layers, and that infiltration into the depths is entirely lacking, something which is in evidence because of the constant drought of the ground. Upon discarding the infiltration theory Volger developed his own condensation theory of the formation of ground waters. According to this theory the atmospheric air with the water vapor in it penetrates the soil and there at the depth where the water table is located the water vapor from the atmosphere condenses forming ground waters. However, Hann (see footnote to reference of Volger) points out a series of substantial errors which Volger allowed in his theory and he therefore discards it. The experiments of Wolny (12) do not corroborate the ideas of Volger. Thus the theory of Volger was discarded. An interesting condition has arisen—Volger's criticism destroyed the infiltration theory; the criticism of Hann destroyed the condensation theory of Volger. At the same time the infiltrationists have ignored the arguments presented by Volger and the followers of Volger could not refute the arguments of Hann. There have been in recent years books on hydrology which give both theories of the formation of ground waters, giving first place tne theory of infiltration and then the theory of Volger, disregarding the fact that the mutual criticism, has destroyed practically both theories. According to the author such a state of affairs came about because the two theories are purely speculative. The followers of these theories have not used experimental methods in developing their views and this led to extreme ideas to simple constructions of logic which obliterate the more complex natural historical nature of the phenomenon. Turning our attention to nature we shall examine the hydrological conditions of the southern steppe where the ground waters are deep (usually 15–20 mm. deep) and where they are separated from the soil and surface waters by dry layers of considerable depth. The investigations of Izmailŝkii [1] conducted on the distribution of water in the soils of the Government of Poltava and especially the work of Vuisotzkii (11) on the same problem conducted in the southeastern

[1] Soil moisture and ground waters.

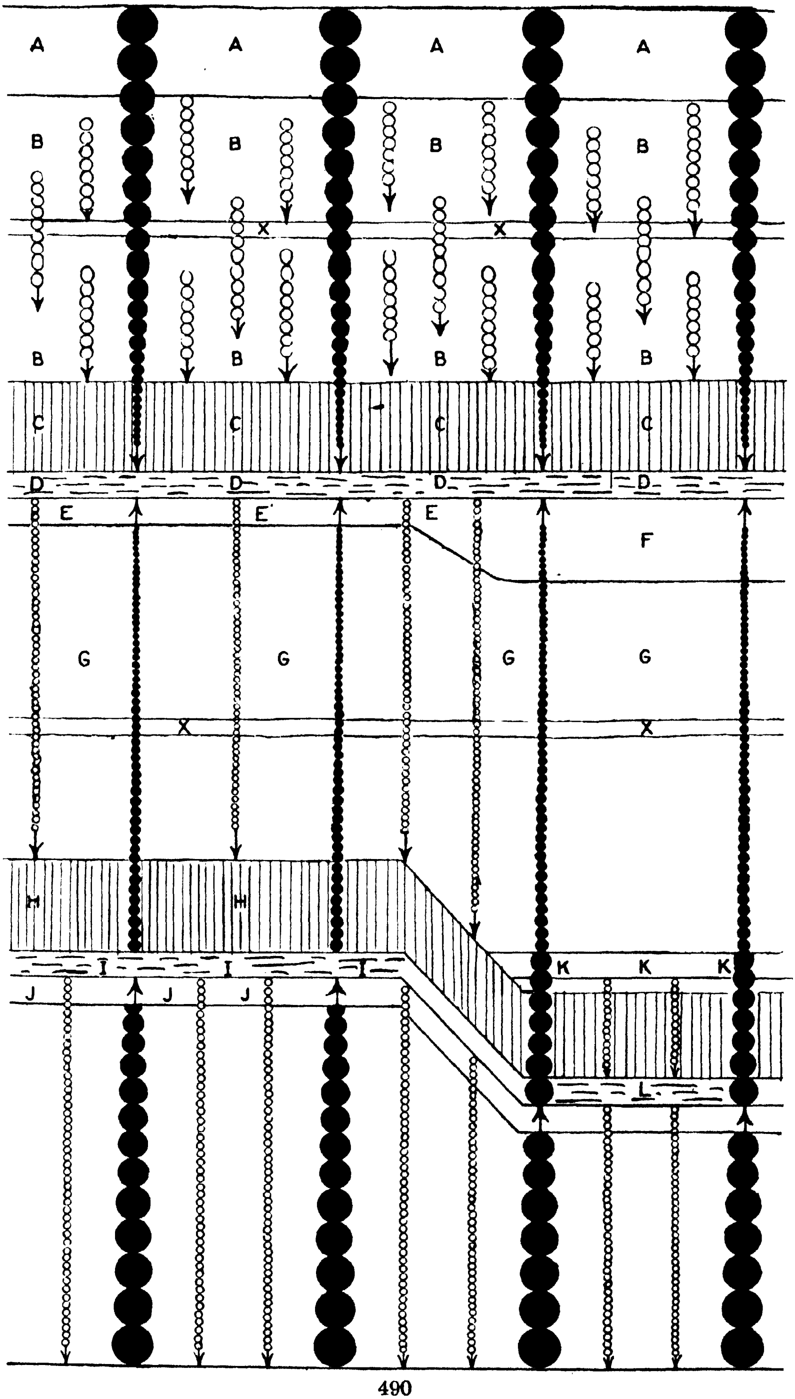
A A A A
B B B B
X X
B B B B
C C C C
D D D D
E E E
F
G G G G
X X
H H
I I I
J J J
K K K
L

FIGURE 8.—Origin of ground waters

1. Black circles represent water vapor. The larger the circle the greater the vapor pressure.

2. All white unshaded areas, excepting A, E, F, K and J represent a horizon with a moisture content equal to the maximum molecular moisture holding capacity.

3. Areas A, C, D, H, I, K and L represent horizons with gravitational water.

4. White circles represent gravitational water at the moment of its movement over horizon given in 2.

A. The suspended soil waters may be observed during the second half of autumn, winter, the first half of spring and after heavy rains in the summer. Depth 1–4 meters (for an analogy see fig. 7-A).

B. A layer with a constant moisture content during the entire year (dead horizon according to Vuisotzkii). The moisture content corresponds to the maximum molecular water holding capacity (for an analogy see fig. 5-F). Depth of layer 14–20 meters.

C. A layer of capillary moisture forming by the ascent of ground waters from the first horizon by way of the capillaries. Depth of layer 2–3 meters (for an analogy see fig. 7-B).

D. The first horizon of ground waters.

E. A relatively impervious layer, underlying the first horizon of ground waters.

F. Absolutely impervious layer—the final limits—in all probability a rare case in nature.

G. A layer with a constant moisture content between the first and second horizons of the ground waters.

H. A layer of capillary moisture forming by the capillary ascent of the ground waters from the second horizon.

I. The second horizon of ground waters.

J. A relatively impervious layer underlying the second horizon of the ground waters.

K. The horizon where the ground waters are formed through condensation of water vapor into a liquid.

L. If the liquid phase formed in K can not, because of certain physical phenomena, remain in this horizon, then the water will drop until new physical conditions of the ground mass will not retain it. In this case the place of the ground water (K) formation may not coincide with its location (L).

X. A break in the drawing.

part of the Government of Yekaterinoslav, Russia, give the following picture (see fig. 8); above the ground waters located at a depth of 15 to 20 m. (fig. 8-D) a moist horizon is observed (fig. 8-C). This horizon is formed by the capillary rise of ground waters (D) and it reaches a height of 2 to 4 m. A constant moisture content of 13 to 16 per cent is then established, fluctuating apparently because of the mechanical composition of the ground as the case may be (fig. 8-B). The last horizon (fig. 8-A), located at the surface, is strongly moistened during the second half of fall, winter and beginning of spring and dries out during the summer and the first half of fall. The depth of this horizon of suspended waters is from 1.5 to 4 m. in various localities. Observing the constant wetness in the third horizon during the entire year, Vuisotzkii assumed that the water from the fourth horizon does not penetrate into the third horizon and therefore he called the third horizon the *dead horizon*. The discovery of a dry layer of soil, between the surface of the soil and the position of the ground waters in the steppe plain, has given a heavy blow to the infiltration theory (Ototzkii). Having recognized the existence of a deep dry horizon between the surface of the soil and the ground waters Izmailŝkii and Vuisotzkii considered it impossible, under the conditions, for the rain water to percolate through. According to their idea this percolation takes place only in various minor depressions of the steppe.

The infiltration theory could not explain the fact which was established analytically by Izmailŝkii and Vuisotzkii. The followers of the Volger theory considered that such observations have given a heavy blow to the infiltration theory. The author compared the picture of the distribution of moisture in the steppe with the distribution and percolation of water studied experimentally in large tubes and gives the following interpretation to the observations of Izmailŝkii and Vuisotzkii:

The moisture in the steppe ground distributes itself in the same way as the water distributes itself in the tall tubes filled with sand. A difference may be observed only in the height of the tube; for clay soils the tubes must be very high in order to be able to observe the phenomena studied by the author in comparatively short sand tubes. The water which runs off from the tubes (Table 14) is analogous to the ground waters which move under the influence of the forces of gravity. The moistened layer in the lower portion of the tubes is analogous to the horizon of the capillary rise of ground waters. The layer with the maximum molecular moisture holding capacity (constant moisture content of our sand being equal to about 2 per cent) is analogous to the dead horizon of Vuisotzkii with a constant moisture. If one should add 1 to 3 g. of water to the surface of the tube a moisture content will be obtained which is analogous to the horizon of the temporary suspended soil moisture, or dropping gravitational water, depending on conditions. If this added water should fall downward in a long tube which contains let us say 20,000 g. of sand, then

in 1 to 2 hours we will not find this water by the ordinary methods of determining soil moisture because the increase in moisture content caused by the addition of water will be less than the error of two controlled determinations in various tubes, whose moisture is in a condition of equilibrium. Apparently Vuisotzkii encountered such a phenomenon. He could not discover minor changes in the moisture content of the dead horizon applying static methods of investigation. The effect of percolation was less than the fluctuations in parallel determinations of the moisture content. Izmailškii knew about the fluctuations and named them as typical of the individual borings. The author thinks therefore that the soil waters of the horizon of temporary moistening (fig. 8-A) may percolate through the dead horizon and join the ground waters in the same way as several drops of a lithium chloride solution percolate through the sand tubes 3 m. high, and still the moisture of the layer with the constant maximum molecular moisture holding capacity remains unchanged. The author is of the opinion that the experiments with the percolation of a solution of lithium chloride explained the condition of the percolation of water in nature through dry layers without saturating them with water.

The gravitational waters combine with the condensation waters and together they form a so-called layer of ground waters. The author considers it expedient not to accept the idea of an impermeable layer. There may be a relatively impermeable layer. Such a layer, under suitable hydrostatic pressure, may allow water to go through and thus the first horizon of ground waters may be connected with the second, the second with the third, etc. The idea of a relative impermeable layer does not exclude the accumulation of water, since in a dynamic conception of this process it is necessary that the inflow of water to that impermeable layer should be greater than the filtration through it. The difference between the inflow and the filtration gives the ground waters. Thus in the complex process of the formation of ground waters the movement of water in the form of vapor from the surface of the soil downward, and from the deeper layers of the ground upward as well as the movement of liquid water under the influence of gravity, are only the separate numbers the sum of which gives the ground waters. The condensation process is a universal process and takes place in all latitudes and under various soil structures. The process of infiltration is lacking in the zone of eternal freezing, in clay deserts and perhaps in the semi-deserts. In the temperate latitudes the condensation process and the infiltration combine and either one is predominating, depending on the climatic and geological conditions of the region.

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INVESTIGATION OF THE RELATIONS OF WATER TO SOIL

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INTRODUCTION

It is indisputable that water is of paramount importance for the development of plants. Along with temperature it is a vegetative factor of the first order. We often notice in agricultural production that larger or smaller crop yields correspond to the larger or smaller proportion of moisture which is, at the time of vegetation, at the disposal of the plant. We usually estimate this need and effectiveness of water with regard to vegetation according to the mean yearly rainfall in the particular district. This basis of calculation, however, is not entirely safe and right, because rain-measuring value is not a deciding factor in plant nutrition; for the plant is not supplied with water from the atmosphere directly, but takes all its water out of the soil.

The water contained in the soil comes from the atmospherical water or rainfall. The value and quality of water, however, is not always the same, even though the rainfall is equal, because the whole of the water does not soak into the soil. On the steeper declivities more water runs away over surface or is lost by evaporation. But the chief cause lies in the fact that the soils themselves do not retain the rainfall water equally on account of their varying capacities for absorbing water. So the sandy soils retain least water, the loamy soils much more, while the clay soils retain most; or, expressed in other words, the quantities of rainfall being equal, the volume of water contained in the soil at the disposal of plants varies largely, and is proportionate to absorbent power or water capacity. Consequently soil moisture is actually a very important vegetative factor which, quite wrongly, of course, is estimated usually in terms of the mean yearly rainfall.

VOLUME OF WATER CONTAINED IN THE SOIL

It is indisputable that we must, therefore, pay more attention to the volume of water contained in the soil if we are studying plant development under different soil conditions. The ascertaining of the volume of water contained in soil is, in view of this, a task of very great importance.

If we study more closely the permeation of soil by rainwater, we find that the uppermost layer is in the first place saturated or oversaturated to the extent of its *full water capacity*. By virtue of *transmissibility* a

certain amount of water, which is temporarily retained here in the non-capillary pores, goes down into the lower stratum. This lower stratum is saturated in this way because the soil retains only that quantity of soaking-down water which it is able to retain for a considerable time by means of its absorbency or capacity. Consequently some time later, when fresh water has ceased to arrive, the water content passes from the stage of full water capacity to that of *absolute capacity*. The period after which I considered the state of absolute capacity to be reached, I fixed at 24 hours.

So by the absolute water capacity I mean *that volume of water which is retained in the soil after 24 hours from the moment of soil saturation.* This power of the soil to retain water is due to the influence of the capillary pores and we can, therefore, deduce that the absolute water capacity value (in view of its volume) is equally an expression of the volume of the capillary pores.

If we presume that when the soil is saturated with water to the point of absolute water capacity, water has soaked down out of all non-capillary pores under the influence of gravity, and that all this water has been replaced by air, we arrive at a notion of a definitely limited stadium of air volume contained in the soil. This is the *air capacity* by which I mean *that quantity of air in the soil which remains there, after the soil has been saturated with water to the point of absolute water capacity.* Then the air capacity is an expression of the volume of the non-capillary pores.

By our derivation of the volumes of non-capillary and capillary pores from air and water capacity values, we are broadening our knowledge of soil structure in its natural state.

The water volume (Wo) and the air volume (Vz) supplement each other to the total volume of soil porosity (P); the following equation, therefore, may be given:

$$P = Wo + Vz$$

If two factors in this equation are known, then the third one may be calculated by finding the difference. As a rule, we ascertain the water volume (Wo) and the total porosity (P), and the air volume (Vz) is the difference between these.

To ascertain the water capacity I introduced a special extracting steel cylinder sharpened into a blade which facilitated the extraction of the soil *in its natural state.* These steel cylinders are pushed inside the small brass cylinder to be driven into the soil. Since the inner cylinders are of exact dimensions, after they are pushed out of the outer cylinder by the soil content and all the overlapping soil has been carefully removed, I can be sure that some of the soil in the brass cylinders remains in its natural state. The diameter of these cylinders was $d = 50.5$ mm., the height was $h = 35.0$ mm., the volume $V = 70.0$ cc.

This diameter which is equal to that of the steel cylinder at the sharp-

ened end, was chosen to enable the instrument to cut out a column of soil with a view to ascertaining the relative transmissibility (i.e. the quality of letting water through). According to our terminology we understand by relative transmissibility *that quantity of water, expressed in cubic centimeters, which runs through a cylinder of a height of 10 cm. and of a base of 10 sq. cm. during 24 hours.*[1] In order to ascertain this transmissibility, this area of 20 sq. cm. which corresponds to a diameter of 50.5 mm. The small inner brass cylinders were to give additional strength to the wall of the instrument, as the insertion of it into comparatively dry soil was attended with considerable difficulty.

In cartography in the field of agronomical soil science throughout Bohemia an extensive investigation of physical soil qualities under different soil conditions was found necessary. So the above mentioned instrument for taking soil samples was essentially simplified.

For several years I have employed small cylinders about 60 mm. in diameter and 100 cc. in volume for taking soil samples of an exact volume in their natural state. These cylinders are made of thin copper sheeting. It is to be noticed expressly that I can cut the cylinders from any steel tube with a thin wall, irrespective of the diameter which I ascertain subsequently. The ascertaining of the diameter or base area is followed by the calculation of the height of the cylinder, in order to get the exact volume of 100 or 200 cc. One end of the cylinder is sharpened on the outer side to form a good blade.

At the same time I cut from the tube a piece about 15 cm. in length, from which I make a rod for piling the rings into the soil. At one side of this tube I brazed a very thin steel cover so that it overlaps at the lower end by some mm. Then the outer end of the cover is sharpened so that the rod may fit sufficiently loosely after it has been placed on the ring and also that it may be driven easily and smoothly into the soil at the time of piling.

For soils of a coarse-grained quality I recommend the use of cylinders 8 to 10 cm. in diameter. The cylinders must be galvanized to prevent them from rusting.

If I wish to take a sample of arable soil, I remove the uppermost layer of crushed soil to a depth of about 5 cm. with a trowel. Then I set the cylinder (fig. 1) with the rod on the levelled area and drive the instrument by slow pressure into the soil so deeply, that the soil penetrates into the rod to a height of 1.5 to 2 cm.

Whether the natural density of the soil has been altered, i.e. whether it has been compressed or not, can be determined by me by means of measurements taken on the rod from its upper edge to the soil surface inside and the same outside. If the measurements are equal, the normal condition of soil density is proved, which means that the soil surface inside the

[1] Kopecký. Die physikalischen Eigenschaften des Bodens 1914.

cylinder cannot have been depressed. This can be checked also by taking the rod out of the soil, which may be accomplished by careful alternating circular motions. In this way the rod is loosened and may be drawn carefully out of the soil. The soil surface above the cylinder in the soil must have the same level as the surrounding area.

If we intend to take the soil sample from any deeper layer we dig out an oblong pit (fig. 2) in the form of a descending staircase and the sample is cut out here by driving a cylinder into the soil.

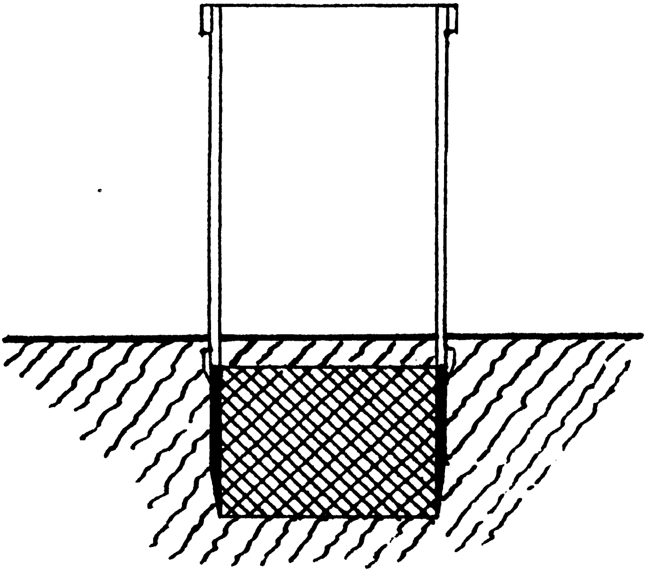

FIGURE 1.—Sampling arable soil

After the rod has been removed, we lift up the cylinder and the sursounding soil with a trowel. The soil is afterwards carefully removed from the cylinder and finally cut off at the ends of the cylinder with a long sharp knife, so that the soil level inside the cylinder may correspond to the cylinder edge. So a soil column inside the cylinder is obtained, having a volume 100 cc. in this case.

WATER AND AIR CAPACITY OF THE SOIL

To ascertain the water capacity we proceed in a somewhat easier way. I cover the galvanized cylinder containing the soil with some pieces of iron sheeting and fix them with a caoutchouc ring. Afterwards I take the sample into a room, remove these pieces of iron sheeting, set the cylinder on a brass sieve and then place these in a flat vessel containing water with the object of over-saturating the soil. Afterwards I set the cylinder and sieve on four-fold filter paper, and add the pieces, which had been

pressed out into the small dish, to the soil in the cylinder and cover it with a reversed watch glass to prevent the water from evaporating. Afterwards I let the water soak down onto the paper through the sieve out of the cylinder for 24 hours, while the cylinder is still on the sieve. In the meantime the cylinder is moved two or three times to another dry place on the paper. After 24 hours the wet soil and sieve are weighed together and subsequently the soil is drawn out of the cylinder. We wait till all is dry, clean the cylinder and sieve with a sharp paint brush, while the pieces of soil that fall off are added to the sample. The weight of cylinder and sieve is the tare which has to be subtracted from the original weights. After the sample has been dried at a temperature of 100 to 105° C., I weigh it in its dry and cold state. The difference between the weight of the soil

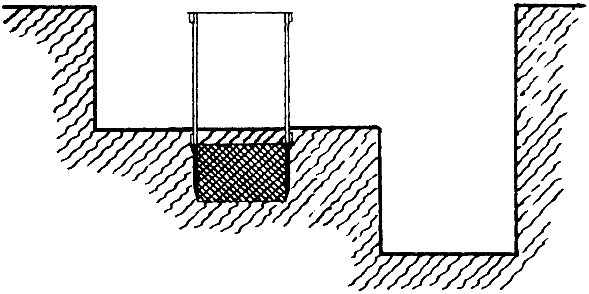

FIGURE 2.—Sampling from deeper layer

in a wet state and its weight in a dry state is equal to the weight of water which corresponds to *the absolute water capacity*.

As I always determine also the weight of soil at the time of taking the sample, by means of the cylinder, the content of water existing in the soil, or *the momentary capacity*, can be ascertained after drying the sample.

The figures obtained indicate the volume of water contained in the stated volume of the cylinder which is 100 cc. It means the percentage of water or volumetric water capacity.

From the weight of the sample so ascertained (100 cc.) the *volumetric weight or apparent specific weight* can be derived.

From the dry sample, I weigh 20 g. of soil for the determination of the *real specific weight* by means of a pycnometer.

Calculation from the difference of these figures gives the *total porosity* content of the soil in its natural state.

In addition to the information so obtained concerning the absolute water capacity and the total soil porosity, this series of physical data may be supplemented by ascertaining the *air capacity* through subtraction of the water capacity from the total soil porosity.

$$Vz = P - Wo$$

The close connection of these data leads us also to the determination of the *optimal figures* relating to water content in soil, or to the determination of the *optimum of water capacity* with the given porosity on the presumption of the most adequate air capacity for different plants.

My long experimentation resulted in the discovery that the most appropriate air capacity for wheat and oats ranges from 10 to 15 per cent (vol.), for barley and sugar beet 15 to 20 per cent, for grass 5 to 10 per cent.

It is necessary that the air content in the soil should be kept up to the given standard with particular porosity while the soil is being saturated with water; this means it is necessary to avoid falling below the designated minimum limit, so that we may retain the minimum requisite for oxidation and biological processes. Under such conditions water is present in the most desirable amount or at the *optimum*.

Consequently I mean by the *optimum water content that total water contained in the soil, which is accompanied by air content ranging between the optimal limits relative to the particular crop, the soil porosity being fixed.*[1]

The optimum water capacity can be calculated from the following relations:

$$\text{Wo} = \text{P} - 10 \text{ to } 15 \text{ (with wheat and oats).}$$
$$\text{Wo} = \text{P} - 15 \text{ to } 20 \text{ (with barley and sugar beet).}$$

The less the figure representing the water content disturbs the equation, the more nearly optimal is the water content. If it is, however, in excess of that of the other side of the equation, it is too large, the *soil being inclined to mud-swamp;* and, on the other hand, if the water content (Wo) is low, then the soil *is drying up.*[2]

If we desire to determine water capacity by means of an experiment in the field, the procedure is easy. I take a tube (fig. 3) of 15 to 20 cm. diameter and about 30 cm. in height, sharpen it at the lower end and drive it into the soil to a depth of about 20 cm. so that about 10 cm. remains exposed. Into the upper part I pour some water to soak down. After the lapse of 24 hours, when the water has penetrated, I take the saturated soil sample from the interior of the cylinder.

This determination of water capacity under natural conditions is often found to be very urgent in the case of the irrigation and flooding of meadows. We have to ascertain the precise amount of water needed for the irrigation if we want, for instance, to moisten a meadow-soil to a depth of 20 cm. or if on the contrary, wish to ascertain the depth to which the water penetrates, if only a limited amount of water be at our disposal.

The determination of water capacity with the particular object of

[1] Kopecký.

[2] If $\text{Wo} > \text{P} - 10$ to 15 the soil being inclined to mud-swamp
If $\text{Wo} < \text{P} - 10$ to 15 Do drying up.

irrigating meadows is a valuable help in the frequent cases of shortage of water and sometimes aids us to determine how to economize water and proceed with our irrigation on a rational basis.

The simplified form of the soil instrument leads us also to a simplification of the procedure for ascertaining *the relative transmissibility of soil* with respect to water.

The diameter of the cylinders in the original cylindrical instrument had exact dimensions (d = 50.5 mm.) in order to obtain a cylinder base of 20 sq. cm. or to obtain any multiple of 10 sq. cm.; for, as mentioned above, the relative transmissibility was defined by me as equal to that quantity

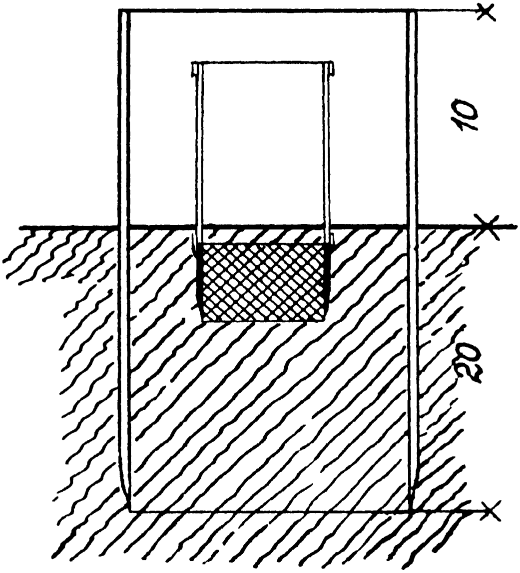

FIGURE 3.—Determining water capacity in the field

of water in cubic centimeters which soaks through the cylinder 10 cm. in height and with a base of 10 sq. cm. in 24 hours. The volume of 1 cc. of water draining through the area of 10 sq. cm. means a fall of 1 mm. in the water level inside the cylinder; the *number of millimeters indicating the fall of the upper water level in 24 hours, therefore, is a numerical expression of the relative transmissibility.*

The diameter of the cylinder or its base area make no difference, therefore, in this result. Consequently cylinders of any diameter may be employed.

For this purpose (fig. 4) I cut a cylinder 10 cm. in height from a thin tube, sharpen the outer side into a blade and drive it downwards into the soil by means of a rod, and so lift up a soil cylinder of 10 cm. in height. After levelling the sample surface at both ends of the cylinder, I fix at the

lower end a brass sieve and put thereon a cylinder, about 15 cm. in height, which is made from the same tube.

Then I connect the cylinders with a rubber ring, which is fastened with a steel spring; or the joint between the cylinders is made waterproof in some other way. If the upper cylinder is to serve as a rod for driving the other cylinder into the soil, a cover made of thin iron sheeting is soldered to it; I can make a waterproof joint between the iron sheeting and the lower cylinder by stopping the intermediate gap with putty made of non-

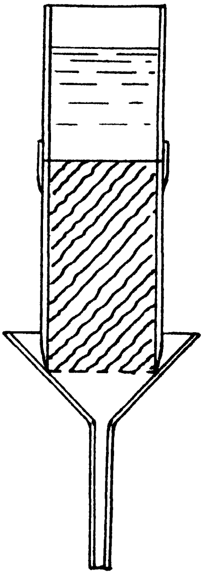

FIGURE 4.—Determining relative transmissibility

vulcanized caoutchouc soaked in C_6H_6 and mixed with a small quantity of tallow.

I pour a little water into the rod and let it soak through. After the soil sample is duly saturated with water and water starts dripping I determine the relative transmissibility.

I pour on the soil surface a water layer 10 cm. in depth and first of all ascertain approximately the degree of permeation. If soil is transmissible and permeation is quick, I add water to the original level and measure the fall of the water after an hour or two. For I wish to permit only a minute fall in the water level, about 5 to 10 mm. lest the hydrostatic water pressure be altered. The results are calculated to a 24 hour basis.

With slightly transmissible soils the fall in the water level is found small, even if measured after 24 hours. The relative transmissibility is found to be comparatively larger at the beginning of the experiment and after further repetitions declines. This is especially noticeable in cases where

water permeation is continued during several days, in order to reach a more exact statement. The explanation of this phenomenon is not difficult; it is caused by the swelling of the colloids. As much continuous soaking into the soil occurs only very seldom in nature, the repetition of the experiment at intervals of one day is advisable.

If I want to ascertain the transmissibility of some soil layer directly under natural conditions, I proceed in an analogous way by ascertaining the water capacity in the field. I drive a tube of considerable diameter into the soil, let the soil layer inside the cylinder be saturated by additions of water, say for 2 days. Then only after adding water to a height of 10 cm. do I commence ascertaining the fall of the level in cm. during a period of 24 hours. The findings under natural conditions do not correspond exactly with the results of the experiment as performed in the cylinder, as the soil in its natural bed coheres with the lower layers.

The simplified methods of ascertaining the relations of water to soil, especially water capacity, through the employment of a simple cylinder of exact volume, as mentioned above, enables us not only to construct the extracting apparatus easily, but also to ascertain physical soil qualities easily and quickly. Thus soil is kept in its natural state at the very time of its examination performed out-of-doors, with a view to drawing up maps showing the qualities or to achieving some technical improvements.

Of course, in addition to a series of cylinders some good portable balance must be carried.

THE LIMITED RÔLE OF CAPILLARITY IN SUPPLYING WATER TO PLANT ROOTS

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INTRODUCTION

It is possible to regard the pore space in soils as consisting either of an assemblage of small cellular units or of irregular thread-like, capillary tubes.

In the first case the concept of the "ideal" soil—equal sized spheres in regular packing—enables a picture of the pore space to be formed. Haines (3) has worked out, for the case of closest or tetrahedral packing, the characteristics of the pore space. It is composed of tetrahedral and rhomboidal cells, there being twice as many of the former as of the latter. Each tetrahedral cell is surrounded by four rhomboidal cells, and each rhomboidal cell by eight tetrahedral cells. The junction between adjacent cells is effected through the apices of the cells, which form a kind of narrow neck. The regularity of the pore space in the ideal soil is of course not found in actual soil, but it is quite legitimate to consider it as essentially of the same type, i.e. cellular, communication between adjacent cells being effected through narrow necks.

In the second case attention is concentrated on the fact that there is a continuous passage through a line of cells and their communicating necks. Such an assemblage therefore is considered as constituting a capillary tube whose dimensions vary systematically along the tube. The pore space as a whole is made up of a collection of these capillary tubes, which are not isolated from one another, but in direct connection. This concept has been developed by Slichter (5) and by Green and Ampt (1, 2). For actual soils the capillaries must be regarded as irregular in width, length and direction.

In considering the movement and distribution of water in soil it has been customary to take the concept of capillary tubes rather than that of the cellular structure, as it is much simpler to picture. In the case of water movement through completely saturated underground strata—which was the main problem in Slichter's work—this is probably legitimate. It is also used implicitly in most textbooks of agricultural science in connection with the capillary rise of water in soil. Simple calculations on this basis lead to the conclusion that the upper layers of soil and plant roots can secure adequate water supply from an underground water table—or a

zone of temporary saturation—even when this is many feet below the surface. Such statements are still common in the textbooks, the low values obtained in laboratory experiments being ascribed to the experimental difficulty of reproducing the right condition of packing. However, when the problem is examined from the concept of the cellular structure of the pore space, results are obtained more in accordance with practical experience. The writer (4) has pointed out that the equilibrium distribution of water in a soil column is controlled by the principle that the water tends to reduce its free surface and hence its surface energy to a minimum. From this, and the fact that the meniscii of the water wedges around the particle contacts touch one another as the volume of the wedges increases, it was inferred that there would be successively above the ground water level (a) complete saturation, (b) complete saturation of smaller interstices and incomplete saturation of larger ones, (c) a region of incomplete and decreasing saturation. Haines, in the important paper already mentioned (3) has shown that this distribution follows from a consideration of the suction-pressure, i.e. the pressure deficiency necessary to draw an air-water interface into the pores of the soil.

It is apparent, therefore, that our ideas of water movement in soil must be revised. As it is known that the attainment of equilibrium conditions of moisture in a soil column is a slow process, it is evident that the conditions of moisture distribution in the field are essentially dynamic, and there is much scope for further experiment in this direction. In the present paper experiments are described which are part of a series now being carried out at Rothamsted in soil cylinders under field conditions. The full results of the first series will be published elsewhere, attention being confined here to the relation between evaporation at the soil surface and the change in the ground water level.

DESCRIPTION OF THE SOIL CYLINDERS

The cylinders used were 6 ft. deep and 2 ft. 6 in. in diameter with a water-tight bottom. They were sunk into the ground with the top edge a short distance above ground level. A thin layer of coarse gravel was first placed at the bottom of each cylinder. An iron pipe 7 ft. long and 2 in. internal diameter, open at top and bottom, was held in a vertical position with its bottom end resting on the gravel. The purpose of the pipe was to enable the position of the ground water level to be observed, as explained later. Soil was then carefully placed in the cylinders, in small quantities and gently compacted in as uniform a manner as possible to within half an inch of the top, a small additional quantity being reserved for addition in the event of a slow settlement of the mass. The cylinders were left for some 7 or 8 years for the soil to settle before systematic experiments began, and the process was aided by periodically drawing out the percolation water through the 2 in. pipe. Some months before readings were started

the top two or three inches of the soil was dug over and weeds removed, after which date the soil was not disturbed except for the removal of seeding weeds as they appeared. Some of the cylinders were filled with coarse sand, others with fine sand, and the remainder with soil. The results considered in this paper were obtained from 7 cylinders, 2 for each of the two grades of sand and 3 for a Rothamsted soil, which was obtained in successive 6 inch layers and filled into the cylinders in the same order. It is defined as "clay with flints" and consists of a medium loam, grading into clay in the lower depths, and contains a number of flints. These were removed by sieving before the soil was put into the cylinders.

METHOD OF EXPERIMENT

In the normal course the moisture in the soil cylinders begins to increase in autumn when the rainfall exceeds the evaporation. At some time during the winter the cylinders have become waterlogged. In the early spring evaporation begins to increase and the level of the ground water falls. The change in this level was followed by measuring the distance between the level of the soil surface and the water level in the 2 in. pipe, by means of a long graduated ruler lowered into the pipe. After the water level has receded a certain distance into the pipe it cannot be seen, but the slight disturbance of the water surface at the instant of contact of the ruler with it was made evident by a momentary flash of light in the tube. No difficulty was experienced in reading the level to a millimeter. The readings were taken once daily at 9 A.M. A parallel series of the usual meteorological observations was also available and in addition a measure of the potential evaporating power of the air over the cylinders was secured by daily weighings of a simple form of atmometer placed on the ground adjacent to the cylinders. The readings in the first series were taken over the period May 1920 to March 1923, the soil being allowed to become waterlogged during each winter and to dry out naturally. The period of observation includes the great drought of 1921, when the normal summer drying was intensified.

DISCUSSION OF RESULTS

The data falls naturally into two broad groups: (a) rise in water table associated with rain, (b) fall in water table during dry spells; in the present paper attention will be confined almost entirely to group (b).

For a preliminary examination the results were graphed by plotting the successive daily positions of the water table against the date. It was found that minor irregularities in the curves were appreciably smoothed out when the time scale was replaced by the atmometer figures. The time scale makes no distinction between a dull day and one of warm sunshine, whereas the potential evaporation from the soil surface is very different in the two cases. The atmometer values show this difference and

their use instead of the time scale is therefore preferable. "Accumulated" values were used, the loss of weight on any one day being added to the total loss of weight up to that day, and this value was plotted against the corresponding measurement of the water table level.

For obvious reasons of space it is not possible to give the full data on which this discussion is based. The general nature of the results is shown in Fig. 1. The curves give the relation between water table level and accumulated atmometer values (the latter to an arbitrary scale) for a coarse sand cylinder and a soil cylinder, for the period from the beginning of May to the end of July in 1922. The incidence of rainfall sufficient in amount to percolate into the soil is shown by the large irregular upward movements in the water level. The remaining portions of the curve are, on the whole, much more regular and indicate the continuous and systematic fall in the free water level in spells of fine weather. The minor fluctuations of water level in the sand are more noticeable than in the soil. Any disturbance of the equilibrium conditions in the water films will tend to promote movement of water into a new position of equilibrium. This movement will be more rapid in sand than in soil owing to the greater average size of the interstices between particles. Hence short period disturbances impressed on the surface of the sand and soil by the constantly varying meteorological factors, will be largely smoothed out in the soil.

A second point of importance is the rapid fall of the water level in the initial stages of drying. At first sight one might have expected a slow fall of water level because, to begin with, the soil is saturated with water. But from a consideration of the suction pressure, or pressure deficiency, as developed by Haines (3), the reason for the rapid initial fall is evident. Haines's curve for the relation between pressure deficiency and moisture content of the soil shows that just below saturation the moisture content changes very slightly for an appreciable increase in pressure deficiency, above its initial zero value at saturation. The system soil-soil water adjusts itself to the increasing suction pressure, by a withdrawal of the free ground water level into the soil to a position of hydrostatic equilibrium. Thus in the early stages a definite free ground water level exists, although the soil above it has a moisture content only slightly less than saturation. In other words, an appreciable drop in ground water level occurs, although only a small amount of water has actually evaporated from the soil itself, and thus the initial rapid fall of water level is explained.

This conclusion also bears on the puzzling field observation that the ground is frequently fit to walk on less than 24 hours after it was so completely saturated that small pools of water formed on the surface, even if there has been little or no evaporation in the interval. The free ground water level has receded a short distance, and although the soil is still nearly at saturation point, the small amount of air in the pores is sufficient materially to reduce its stickiness.

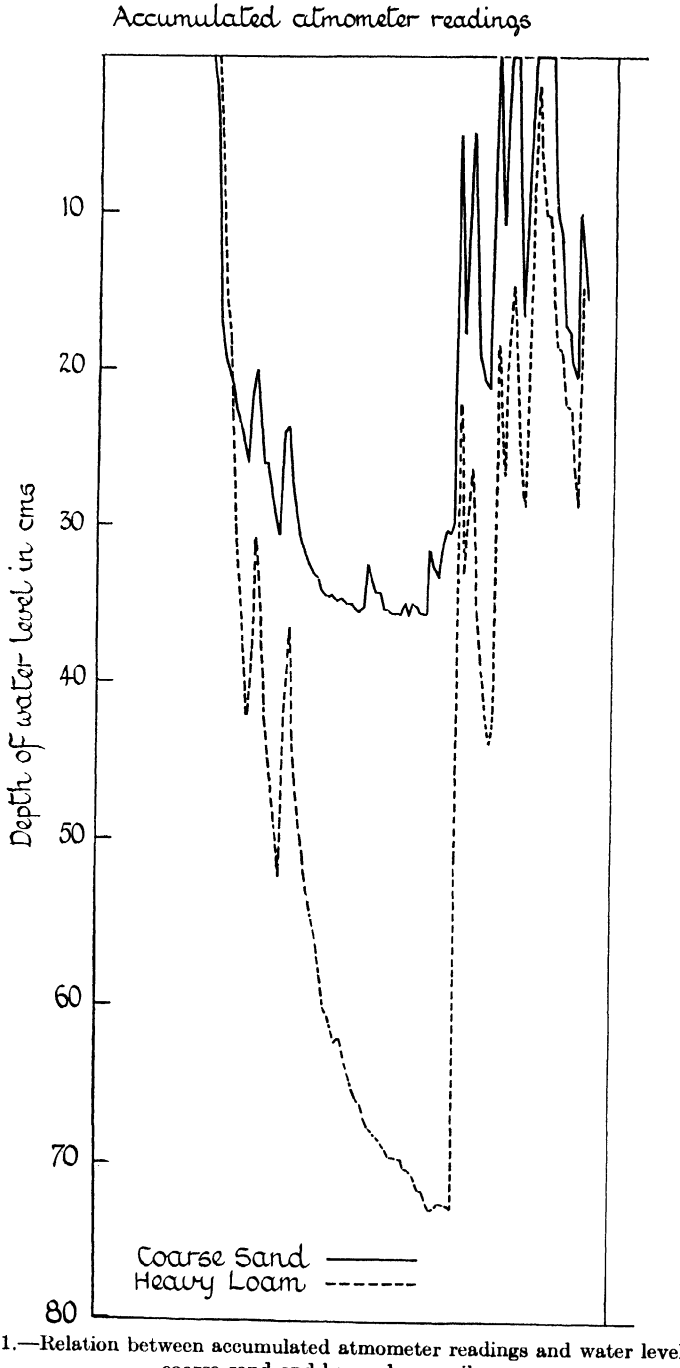

FIGURE 1.—Relation between accumulated atmometer readings and water level for coarse sand and heavy loam soil

The third point brought out by Fig. 1—especially by the smoother soil curve—is a distinct tendency for those portions corresponding to fine weather at the soil surface to form displaced sections of one continuous curve. Such a curve can be built up if each of the individual portions referred to is transferred parallel to itself an appropriate distance to the left of the diagram. The continuous curve so formed may be regarded as showing how the free water level would fall in an initially saturated soil during a continuous and unbroken drought. It thus represents an extreme and simplified state of affairs, unrealizable in practice in temperate

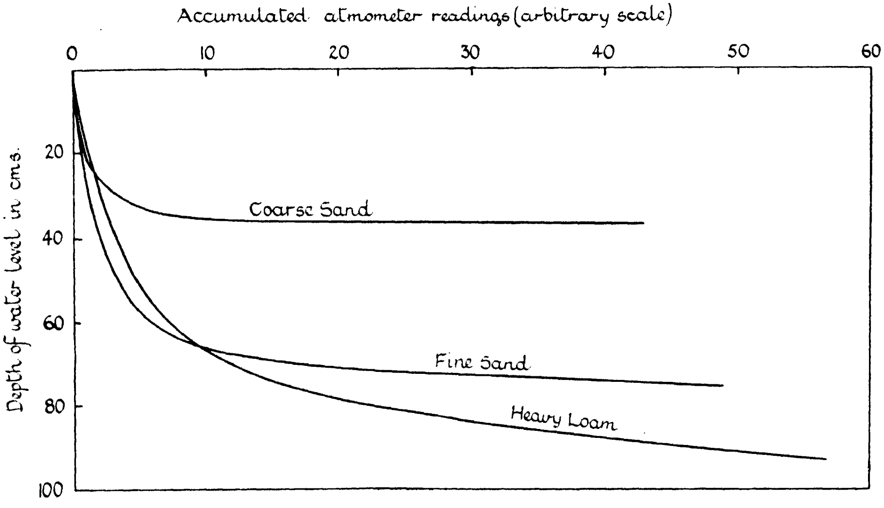

FIGURE 2.—Mean curves for relation between water level and accumulated atmometer readings

climates, although the great drought of 1921 afforded a fairly close approach to this condition. Composite curves were constructed in this manner, the whole of the 3 years' data being used for this purpose. A very few of the portions had a distinctly different average slope from the corresponding section of the mean curve, but the greater number fell so closely on a mean curve that no difficulty was experienced in tracing the latter. The mean curves obtained in this manner are shown in Fig. 2. The accumulated evaporation figures of the atmometer are used as abscissae for the reason already given, and are equivalent to a duration of some 6 to 7 months. The curves lend themselves to a mathematical treatment. This has been done and will not be considered in the present paper, but published together with other data elsewhere.

The curves show that the initial rate of fall is greater, the coarser the material, and progressively decreases as the level itself recedes below the surface. The reason for this is evident from simple considerations. The

soil loses moisture by evaporation from the upper layers. When the free water level is near the surface, not only is the distance the water must travel to the region of evaporation a short one, but the water films themselves are thick. As the water level recedes, water has to travel a longer distance to reach the surface, and the water films also become thinner, and restrict the rate of movement. The latter effect is augmented by an additional thinning of the films due to evaporation proceeding at a faster rate than that of the upward capillary movement of water. In all probability this process continued until a natural mulch formed on the surface, but no direct test of this could be made without disturbing the soil.

Although the rate of fall of the water level decreases systematically, it is clear from the curves that it is fairly rapid down to a certain distance, below which it slows up markedly. This effect is more marked in the case of the two sand curves than in the soil. In the coarse sand, after the water level receded to about 35 cm. below the surface, practically no further movement occurred, although the accumulated evaporation values for the atmometer had only attained to about one-third of their final value at this point. The corresponding value for the fine sand is about 70 cm. In the case of soil the point is less definite although the slowing up of the rate is clearly shown below 85 cm. Hence, when the free water surface is below these levels its power of supplying water to the upper layers of soil is negligible. Thus even in heavy soils, the range over which capillarity can be regarded as effective in supplying any quantity of water in a reasonable time is only about 90 cm. or 3 feet. This figure is, if anything, an overestimate, as in the present experiments the initial saturation of the soil and the sustained evaporating conditions of the 1921 drought were both favorable to a condition in which the capillary power of the soil should show to advantage.

The results of laboratory experiments on capillary rise, which have usually been considered as giving values lower than obtain in practice, are therefore much nearer the truth than hitherto supposed. In assessing the total depth of soil supplying moisture for plant growth, this distance of 3 feet should be added on to the average depth of penetration of the roots, since the reduction of soil moisture content by absorption at a root hair will induce capillary movement of water from the soil below. Nevertheless, the total available quantity of moisture in a period of drought is not great. The plant root does not wait for but goes in search of the moisture content. The practical consequence is important. It is necessary to conserve by all available methods the moisture in the top 2 or 3 feet of soil and to encourage deep root development, to prevent the crop suffering in periods of drought. It is found, even in Britain, with its adequate and well distributed rainfall, that it is essential to adapt our cultivation operations so as to conserve the store of water in the upper layers of the soil. In dryer climates and especially in irrigation districts where the flooding

of the land causes the surface soil to run together and thus slow up the rate of percolation, the necessity for adequate soil cultivation to produce mulches is particularly important.

SUMMARY

Over a period of 3 years, including the great drought of 1921, daily measurements have been made at Rothamsted of the ground water level in soil cylinders 6 feet deep and closed at the bottom to prevent drainage. The surface of the soil was kept free from vegetation and exposed to the meteorological conditions. The ground water level values have been plotted against the accumulated evaporation figures obtained from a simple atmometer. Attention has here been confined to the sections of these curves referring to periods of drought. These sections fall on a smooth curve which can be considered as representing the change in ground water level in the soil, initially saturated, when constant evaporation conditions are maintained at the surface. The initial rapid fall in the ground water level is explained by consideration of the suction pressure developed in the cell-like pore space of the soil. Below the approximate depths of 35 cm. in coarse sand, 70 cm. in fine sand, and 85 cm. in a heavy loam soil, the fall of the ground water level is very slow. The results show that the supply of water by capillarity either to the soil surface or to the region of actively absorbing roots is of a limited nature, and do not support the widely held contrary opinion. They emphasize the importance of cultivation methods aimed at conserving the soil moisture not only in dry climates, but also in humid conditions where the rainfall is both adequate and well distributed.

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SOME FACTORS AFFECTING THE MOISTURE EQUIVALENT OF SOILS

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Studies previously reported (7) dealt mainly with the effect on the moisture equivalent of the amount of soil used in its determination. Repeated moisture equivalent determinations of thoroughly mixed 30 g. samples of the same soil failed to give concordant results, even though these determinations were made with all the precautions heretofore suggested. This led to a further detailed study of the technique involved in the moisture equivalent method and the results are reported in this paper.

PROCEDURE USED IN THE STUDY

Soils of distinctly different character and covering a wide range of moisture equivalents were used in this investiagtion. The designation of each soil which is used throughout this paper, its classification taken from the local soil survey map, and the locality from which the soil was collected are listed in Table 1. All of the stock supplies of the different soils used were collected by scraping off the upper few inches to remove the vegetation and the samples were taken from a depth of from about 4 to 12 inches. Some of the soils were dry and others were wet when they were taken from the field.

The centrifuge cups after being carefully fitted with squares of filter paper were filled with from 30.5 to 31.5 g. samples of air-dried soils to give about 30 g. of water-free soil. All of the samples were passed through a 2 mm. sieve before being placed in the centrifuge cups. The surface of the soil in the cups was smoothed off to give the surface toward the axis of rotation approximately the same curvature as the centrifuge head. However, a comparison of the results of tests made with samples smoothed and curved with those in which this precaution was not taken is given in this paper and it was found to be unnecessary (Table 12).

The centrifuge cups were then placed in tin cake pans 22 cm. square and 2.5 cm. deep which conveniently held the 16 centrifuge cups. About 500 cc. of distilled water were poured into the pan and this amount, which is equal to about 1 part of water to 1 part of soil by weight, completely covered the surface of the soil in the cups. This is a departure from the method suggested by Briggs and McLane (1, 2).

The samples were allowed to stand in this saturated condition for 24 hours, except as otherwise noted. They were then removed from the water, allowed to drain for a period of about 30 minutes and placed in the centrifuge. The effect of drainage was not studied.

TABLE 1.—Designation, classification and location of soils

Soil	Classification of soil taken from soil survey map	Location from which soils were taken
A	Twin Falls silt loam	Twin Falls, Idaho
B	Yolo fine sandy loam	University Farm, Davis, California
C	Yolo clay	Near Woodland, Do
D	Yolo silt loam	University Farm, Davis, Do
E	Oakley fine sand	Experimental Irrigation Tract, Delhi, Do
F	Capay clay	Near Davis, Do
G	Columbia silt loam	Near Sacramento, Do
H	Stockton clay adobe	Pleasant Grove, Do
I	Columbia sand	Near Wheatland, Do
J	San Joaquin loam	Near Wheatland, Do
K	Sierra sandy loam	Vista, Do
L	Yolo fine sandy loam	University Farm, Davis, Do
M	Placentia loam	Anaheim, Do
N	Oakley fine sand	Experimental Irrigation Tract, Delhi, Do
O	Yolo clay	University Farm, Davis, Do
P	Yolo fine sandy loam	University Farm, Davis, Do
Q	Capay clay	Plainfield, Do
R	Willows clay adobe	Zamora, Do
S	Yolo silt loam	University Farm, Davis, Do
TC	Tehama clay	Zamora, Do
TL	Tehama loam	Arbuckle, Do
U	Umatilla sand	Oregon
V	Catherine loam	Do
W	Redmond sandy loam	Do
X	Gila silt loam	Mesilla Valley, New Mexico
Z	Brazito fine sand	Do
AL	Anthony sandy loam	Do
GC	Gila clay	Do

The moisture equivalent centrifuge used in these investigations was the latest model manufactured by the International Equipment Company. The speed governor supplied with the machine was removed. The speed of the centrifuge was regulated by hand manipulation of the rheostat since it was found that much closer regulation could be secured in this way than with the centrifugal governor supplied with the machine. The speed of the centrifuge was indicated by a Frahm speed indicator and frequently checked by a Hassler Tachometer which accurately indicated

the speed to 2 r.p.m. The variations did not exceed 50 r.p.m. on either side of 2440 r.p.m.

The centrifuge was brought up to speed within 5 minutes and the samples centrifuged for an additional 30 minutes. The centrifuge was stopped within a period of one minute after turning off the power. The samples were removed from the centrifuge cups, the filter paper discarded, and the soil placed in small weighing cans which were all of the same weight. The moisture determinations were made in the usual way. A beam balance was used, the weights being recorded to 0.05 g. except as otherwise noted when a more delicate balance was used and the weights were read to 0.01 g. The usual practice was to dry the samples in an electrical oven and an effort made to dry all of the samples as near 110° C. as possible. The variations in temperature throughout the several electrical ovens tested during the course of these studies were surprisingly great even though the thermostat controls could be regulated to hold the temperature fairly constant at any point in the oven. This was one reason why the small weighing cans were used. These were spice cans 60 mm. by 33 mm. cut off to a depth of 33 mm. and could be packed closely together on one shelf in the oven, so that the 16 cans for one centrifuge set occupied a small space. Thus all of the samples from one set could be placed under practically the same drying conditions.

The moisture equivalents given in the following tables in each case are the percentages of water retained by the centrifuged samples calculated on the basis of the dry weights of the soil. Each value is the average of at least 4 determinations. Early in these studies rather wide variations were found in the moisture equivalents of samples taken from the same well mixed stock supply of soil when the samples were centrifuged at different times, that is, not in the same centrifuge set or load. These variations were observed although very close agreement was obtained between individual samples of the same soil run in the same set. Therefore, in investigating the several factors which were thought might affect the moisture equivalent comparisons are made between the values obtained with the same kind of soil when run in the same centrifuge set whenever this was possible. It was not possible to reproduce satisfactorily the moisture equivalent of samples centrifuged at different times until after the causes of these variations became known as the studies progressed.

CONDITION OF THE SOIL PREVIOUS TO PREPARATION OF SAMPLES FOR CENTRIFUGING

The conditions of the soil previous to preparation of samples for centrifuging which were studied were storage of dry soil at different temperatures, previous moisture condition of the soil, cropping, and oven drying.

STORAGE OF DRY SOILS AT DIFFERENT TEMPERATURES

The effect of storing air-dried soil under different temperatures was investigated. Air-dried samples were exposed in the laboratory and in cold storage subject to changes in hygroscopic moisture. Other samples were placed in dessicators over concentrated sulfuric acid in the laboratory and in cold storage. The temperature varied in the cold storage from about 1 to −10° C. and the soils were frozen for considerable periods. The temperature in the laboratory varied from about 0 to 45° C. These soils were exposed in this way for periods of from 5 months to 1 year, but no significant differences were found in the moisture equivalents of the different samples.

Moisture Equivalents of Air-Dried and Moist Soils

The stock supply of soil in each case was thoroughly mixed by heaping and turning the pile. A portion of the stock supply of those soils which were moist when taken from the field was placed in screw-top jars and stored in the moist condition for periods of from 1 week to more than 3 months. All of the samples of moist soil were taken from the field after being wet by rains for several months, consequently some of them were too wet to be sieved without puddling them. These soils were allowed to dry partially before placing them in the jars. The moisture equivalents of samples of soils which were air-dried and stored in a moist condition are given in Tables 2 and 3. At the time the moist samples, moisture equivalents of which are reported in column 3 of Table 2, were taken from the jars to prepare them for centrifuging, duplicate samples were placed in pans and allowed to air-dry. After several days the moisture equivalents of these air-dried samples were made at the same time with samples of the original air-dried stock samples of the same soil, and the values obtained are listed in columns 5 and 6 of Table 2. The moisture content of the moist soils previous to saturating them for centrifuging is listed in column 8 of Table 2, and are given as percentages of the moisture equivalent. The moisture content of the air-dried soil E was 0.4 per cent while that of the moist samples was 1.7 per cent, or only 35.2 per cent of the moisture equivalent. The moisture determination was made after the moist soil had been taken out of the jar in which it was stored and had been exposed to evaporation for a short time. This soil dries very rapidly and it is probable that its moisture content in the jar was higher than that given in the table. The soil seemed to be moist when rubbed between the fingers.

The effect on the moisture equivalent of the moisture condition of the soil previous to centrifuging and of air-drying moist soils may be seen by comparing the data given in column 3 with those in column 2, and those in column 6 with those in column 5 of Table 2, respectively, since these

samples were centrifuged at the same time. It is clear from Table 2 that moisture equivalents of samples in a moist condition previous to centrifuging may vary from those of air-dried samples of the same soil. The moisture equivalents of the moist samples of 7 soils varied significantly [1] from those of air-dried samples of the same soils. The moisture equivalents of samples of some of the air-dried soils were larger than those of moist samples and in other cases they were smaller. There apparently is no relation between the amount of moisture in the moist samples and the variation in moisture equivalent between moist and air-dried samples. If the 16 soils are divided into two groups, those having differences between moisture equivalents of air-dried samples and moist samples larger than 0.8 per cent forming one group, those with differences of 0.8 per cent or less forming the other group, the average value for the moisture content of the moist samples, expressed as a percentage of the

TABLE 2.—Moisture equivalents of samples in air-dried or moist condition previous to making the determination

Soil	Air-dried soil	Moist soil	Difference	Air-dried soil	Moist soil subsequently air-dried	Difference	Moisture in moist samples previous to saturating. Percentage of moisture equivalent
E	4.8[a]	4.5[a]	+0.3				35.2
K	12.0	11.9	+0.2				70.5
TL	13.4	12.6	+0.8	12.6[a]	12.7[a]	−0.1	87.3
I	13.5	15.8	−2.3				85.9
TC	16.3	17.4	−1.1	16.1	16.5	−0.4	88.0
J	16.9	17.3	−0.4				60.2
G	18.4	18.9	−0.5				64.8
L	19.0	19.2	−0.2				89.1
P	19.4	20.6	−1.2	19.4	19.4		88.0
H	21.8	26.2[b]	−4.4				65.1
S	21.7	21.9	−0.2	22.1	21.9	+0.2	77.8
R	22.8	21.6	+1.2	22.0	22.3	−0.3	80.9
O	27.3	26.5	+0.8	27.7	27.6	+0.1	61.9
Q	28.5	32.7	−4.2	28.9	29.5	−0.6	77.2
C	30.1	28.2	+1.9				53.2
D	31.6	30.4	+1.2				71.3

[a] Moisture equivalents of each soil in columns 2 and 3 are from samples run in the same set and those in columns 5 and 6 are from samples run in the same set.

[b] Free water on top of sample after centrifuging.

[1] The writers believe that when 4 samples are run in one centrifuge set and 4 in another set a difference in the average moisture equivalents of 0.9 is significant. (See Table 22.)

moisture equivalent, is 76.2±2.96 for the first group and 68.3±4.14 for the second group. The difference is 7.9±5.09 which is not significant.

While the moisture equivalents of some of the moist samples differed significantly from those of the air-dried samples, air-drying the moist samples seemed to restore the samples to a condition which gave about the same moisture equivalent as the original air-dried samples. Apparently the change in the moistened soil is only temporary.

Moisture equivalents of moist and air-dried samples of the same soil were repeated at another time. The thickness of layer of the centrifuged samples, or the depth of soil in the cup, was measured by the direct micrometer measurement method (7, p. 31). The results of these measurements are given in Table 3. The thickness of layer of all of the centrifuged samples which were moist previous to preparation for centrifuging, except the fine sand (soil E) was less than that of the air-dried samples but there is no correlation between the thickness of layer and the difference in moisture equivalents of the air-dried and moist samples. It should be noted that in this test the variations in the moisture equivalents of the air-dried and moist samples are insignificant, except in the case of soil H. Free water accumulated on the surface of the moist samples of this soil during centrifuging.

TABLE 3.—Thickness of layer of centrifuged soils of air-dried and moist samples

Soil	Average thickness of layer of 30 g. samples of dry soil in cans		Moisture equivalent	
	Air-dried samples	Moist samples	Air-dried samples	Moist samples
	cm.	cm.		
E	0.815[a]	0.847	4.9	4.6
K	0.776	0.732	11.9	11.6
J	0.871	0.834	16.9	17.0
G	0.957	0.942	18.4	18.8
H	0.859	0.761	21.8	28.3[b]
D	1.027	0.960	31.5	30.8

[a] Each value is the average of 4 samples run in the same centrifuge set.
[b] Free water on top of samples after centrifuging.

Moisture Equivalents of Cropped and Non-Cropped Soils

Samples were taken from thoroughly mixed and screened stock supplies of air-dried soils placed in containers and plants were grown in them. The soils were repeatedly wetted and dried during the time plants were growing. After the plants died, 6 of the soils reported in Table 4 were allowed to stand in the open exposed to rain throughout the winter and

consequently were saturated for long periods. They were spread out in thin layers and allowed to air-dry. They were then sieved through a 2 mm. screen and prepared for centrifuging in the usual manner. The moisture equivalents given in Table 4 of the air-dried samples from the original stock supply which were not cropped are the averages of from 12 to 24 determinations of each soil. With the exception of soil L, these samples were not run at the same time as were the samples of the cropped and repeatedly wet soils. Furthermore, at the time these tests were made the effect of differences of temperature during the time the samples were saturated previous to centrifuging and during centrifuging was not known. However, the fact that no significant differences were obtained between the moisture equivalents of the soils which were cropped, repeatedly wetted, and then air-dried, and those of air-dried samples, indicates that no changes which affect the moisture equivalent have occurred in these soils.

TABLE 4.—Moisture equivalents of soils stored in air-dried condition and of soils cropped and repeatedly wetted but air-dried just before making the determinations

Soil	Air-dried	Plants grown	Cropped and repeatedly wetted but air-dried before centrifuging
I	13.0[a]	Corn	13.5[a]
B	16.2	Wheat	16.7
K	12.1	Corn	11.7
J	16.9	Corn	16.8
L	18.8	Corn	19.6
H	21.8	Corn	21.5
A	23.1	Wheat	23.6
F	26.8	Wheat	27.4
C	29.7	Wheat	30.1
D	30.8	Corn	30.3

[a] Cropped and non-cropped samples run in the same centrifuge set. All other moisture equivalents made at different times. Each value in column 2 is the average of from 12 to 24 samples and each one in column 4 is the average of 4 samples.

The moisture equivalents in column 4 of Table 4 were made without removing the roots from the soil. The moisture equivalents of samples of soils on which wheat had been grown and from which roots large enough to be seen with the unaided eye were removed, and the moisture equivalent of similar samples of soil from which roots were not removed are given in Table 5. It is clear that the amount of roots in the samples reported in column 3 of Table 5 did not influence the moisture equivalent even though the soils were permeated with them.

TABLE 5.—Moisture equivalents of samples from which roots were removed and similar samples containing roots

Soils	Samples from which roots were removed	Samples containing roots
B	17.0[a]	17.1
A	23.9	23.9
F	27.0	27.2
C	30.2	30.3

[a] Each moisture equivalent is the average of 4 samples and the samples for each soil were run in the same centrifuge set.

Moisture Equivalents of Oven-Dried Samples

The effect of oven-drying the soil previous to making moisture equivalent determinations is indicated in Table 6. The air-dried soils were divided into two portions, one portion being dried at about 110° C. for 48 hours. Moisture equivalent determinations of the oven-dried samples were made shortly after removing the samples from the oven and in no case were they allowed to stand in the laboratory for more than a few days. The data in Table 6 show that the moisture equivalents of all of the oven-dried soils tested were smaller than those of the air-dried samples, but the difference in some soils was not significant. The soils used in this test did not contain a large amount of organic matter. It is probable that greater differences might have been obtained if the organic content of the soil had been higher.

TABLE 6.—Moisture equivalents of air-dried and oven-dried soils

Soil	E	K	I	B	J	G	L	A	H	F	C	D
Air-dried	4.9[a]	12.1	13.5	16.1	16.9	18.4	19.0	22.8	21.8	26.5	30.1	31.6
Oven-dried	4.5	11.5	12.4	15.4	16.9	15.9	18.0	20.0	21.7	26.4	29.6	30.7
Difference	0.4	0.6	1.1	0.7	0	2.5	1.0	2.8	0.1	0.1	0.5	0.9

[a] Moisture equivalents for soils E, J, H, G, K, L and D are the averages of 8 determinations, 4 of the air-dried and 4 of the oven-dried samples were run in the same centrifuge set. The moisture equivalents for the other soils are the averages of 4 samples in each case. The 4 air-dried and 4 oven-dried samples were run in the same centrifuge set.

Some of the oven-dried soils were kept in the laboratory and allowed to air-dry from May, 1926, to January, 1927, and moisture equivalents were then determined. Four of the soils which showed the largest difference between moisture equivalents of the air-dried and oven-dried (Table 6), were used in the test reported in Table 7. The moisture

equivalents of the air-dried samples reported in column 5 were different from those of air-dried samples in column 2 although they were taken from the same stock supply of soil. They are much nearer the moisture equivalents of the oven-dried samples given in column 3. It would seem from these data that the moisture equivalent of the oven-dried samples had not changed but, since the samples were not run in the same centrifuge set, such a comparison may not be reliable. Indeed, the differences in moisture equivalents in columns 2 and 5 of Table 7 are typical of the variations which have been repeatedly observed when samples of the same soil have been centrifuged at different times. These variations cannot be attributed to long storage, because it was observed repeatedly in the course of this study that the moisture equivalents of air-dried soils were not altered during long storage extending over a year or more. A possible explanation for the difference in moisture equivalents of the air-dried samples may be found in the fact that the temperature in the laboratory in May, 1926, when the first air-dried samples were run, reached as high as 45° C. while in January, 1927, the temperature was close to 20° C. It will be shown later in this paper that temperature differences both at the time of centrifuging and during the time the samples are saturated previous to centrifuging do affect the moisture equivalent.

TABLE 7.—Moisture equivalents of air-dried and oven-dried soils shortly after oven-drying and after the oven-dried soils had been allowed to air-dry for 9 months

Soil	Determinations made in May, 1926, shortly after oven-drying			Determinations made in January, 1927, after oven-dried soil had air-dried		
	Soil air-dried, but not oven-dried	Oven-dried soil	Difference	Soil air-dried but not oven-dried	Oven-dried soil	Difference
I	13.5[a]	12.4	1.1	13.1[a]	12.5	0.6
G	18.3	15.7	2.6	16.8	16.1	0.7
L	19.2	17.8	1.4	18.7	18.0	0.7
D	31.8	30.8	1.0	30.7	30.3	0.4

[a] The moisture equivalents are the averages of 4 samples. In each case the air-dried soil was run in the same centrifuge set with the oven-dried soil.

The data in Table 7 might suggest that changes affecting the moisture equivalent taking place on drying the soils at about 110° C. will be restored on air-drying the samples. However, even if this is true, other data tend to show that the restoration of oven-dried samples to their original condition in so far as the moisture equivalent is concerned is a very slow

process. Therefore, it is believed that soils which have been dried in the oven should not be used for the most reliable comparisons of moisture equivalents.

PREPARATION OF SAMPLES FOR CENTRIFUGING AND CENTRIFUGING THE SAMPLES

The effect on the moisture equivalent of grinding and pulverizing the samples in different ways, the manner of wetting the samples and the duration of the period of saturation, puddling the saturated samples, the changes in temperature during saturation and centrifuging and of balanced and unbalanced centrifuge loads was studied.

Grinding and Pulverizing the Samples

The method of grinding and crumbling the lumps of soil to prepare the sample for centrifuging was found to affect markedly the moisture equivalent. Samples taken from the thoroughly mixed stock supplies of air-dried soils were ground in a machine made by the Enterprise Manufacturing Company of Philadelphia, Pennsylvania. The machine-ground soil was then passed through the 2 mm. sieve. Samples from the same stock supplies of soils were prepared for centrifuging by sieving. The soil was placed in the sieve and the lumps were crumbled and forced through with the pressure of the fingers alone. In a few cases the very large lumps of soil were broken up by mechanical means, but care was taken not to pulverize the soil. This method of preparing the samples was followed throughout this investigation except as otherwise stated. The results of the moisture equivalent determinations of ground soils and sieved soils are given in Table 8. Machine grinding increased the moisture equivalent in every case.

TABLE 8.—Moisture equivalents of sieved and machine-ground soils

Soil	E	I	B	L	F	C
Machine-ground	5.6[a]	15.5	17.9	20.3	29.4	31.2
Sieved	4.2	13.0	16.4	19.7	26.6	30.2
Difference	1.4	2.5	1.5	0.6	2.8	1.0

[a] The moisture equivalents are the averages of from 4 to 12 samples. Four machine-ground samples were run in the same set with 4 sieved samples in each case.

Samples of the air-dried soils were prepared by pulverizing the lumps in a steel mortar with a pestle and sieving the soil through a 2 mm. sieve. Four different operators prepared samples in this manner and the results of the test on 6 of the soils are given in Table 9. The moisture equivalents were markedly influenced by the degree of pulverization each opera-

tor thought necessary, each of whom was instructed merely to reduce the soil to a condition so that it could be sieved through the 2 mm. sieve. The differences in the moisture equivalents of samples pulverized by the different operators persisted even though the samples were saturated as long as 125 hours.

TABLE 9.—Moisture equivalents of soils pulverized in a steel mortar with pestle by four different operators

Soil	Operator				Maximum difference between averages
	1	2	3	4	
I	17.0[a]	15.1	14.3	16.1	2.7
J	18.6	17.9	17.9	17.8	0.8
L	21.7	20.6	20.5	21.0	1.1
H	23.1	21.2	21.1	21.2	2.0
A	23.2	25.3	24.4	23.3	2.1
F	27.8	28.6	27.1		1.5

[a] The moisture equivalents are the averages of 4 samples. The samples of each soil were run in the same centrifuge set.

Samples of air-dried soils were pulverized by spreading them in a thin layer and rolling with an ordinary typewriter platen or roller. The

TABLE 10.—Moisture equivalents of soils pulverized by three different operators by rolling with rubber roller and the moisture equivalents of the same soils without rolling

Soil	Sieved	Rolled by operator			Maximum difference in average of rolled samples	Maximum difference between sieved and largest average of rolled samples
		1	2	3		
I	14.2[a]	15.3	15.4	13.9	1.4	1.2
B	16.4	17.3	17.1	16.4	0.9	0.9
G	17.2	18.7	19.0	17.7	1.3	1.8
J	17.3	17.5	17.6	17.4	0.2	0.3
L	19.2	20.9	20.4	19.7	1.2	1.7
H	21.5	21.6	21.9	21.1	0.8	0.4
O	27.5	28.0	27.9	27.7	0.3	0.5
D	30.3	30.7	30.5	30.3	0.4	0.4

[a] The moisture equivalents are the averages of 4 samples. The samples of each soil were run in the same centrifuge set.

moisture equivalents of 8 soils prepared in this way by three different operators and the moisture equivalents of the same soils prepared by crumbling and forcing the lumps through the sieve with the fingers are given in Table 10. In this case, also, considerable variations in moisture equivalents occurred in the samples rolled by the different operators but the differences generally were smaller than those obtained when the samples were pulverized with mortar and pestle.

Much less variation in the moisture equivalents were obtained when the soil was crumbled and forced through the sieve by the fingers. Samples of 7 soils prepared in this way by four different operators were centrifuged and the results are given Table 11.

TABLE 11.—Moisture equivalents of soils sieved by different operators

Soil	Operator				Maximum difference between averages
	1	2	3	4	
J	17.2 [a]	17.2	17.2	17.1	0.1
L	19.6	19.5	19.6	20.3	0.8
H	21.6	21.4	21.4	21.8	0.4
A	22.8	23.3	23.2	23.2	0.5
F	26.5	26.8	26.7		0.3
C	30.2	30.2	30.1		0.1
D	31.2	31.5	31.3	31.5	0.3

[a] The moisture equivalents are the averages of 4 samples. The samples of each soil were run in the same centrifuge set.

The surface of the smoothed soil was brought to about the same curvature as that of the centrifuge head. This was done with the purpose of making the block of soil uniformly thick. This was the method used throughout this investigation, but near the end of the experiments samples of air-dried soils were prepared in this way and centrifuged in the same set as were samples which were placed in the centrifuge cups and lightly tapped with the fingers to level the surface of the soil. The results of these tests are given in Table 12. The moisture equivalents of the samples treated in these two ways agreed closely. However, it is surprising that in the majority of the cases the samples which had been leveled by tapping the cup with the fingers had smaller probable errors than those which had been smoothed and curved. These results indicate that no special care is necessary to smooth the surface of the soil in the cup before saturating them. It was noted in wetting the samples that the soils in many cases swelled and changed the shape which destroyed the object sought for in leveling them with the special device.

TABLE 12.—Moisture equivalents of samples with inner surface smoothed and curved and of samples which were leveled by tapping with fingers

Soil	Smoothed and curved	Leveled by tapping with fingers	Difference between largest and smallest moisture equivalent in each set		Probable error of a single determination	
			Smoothed and curved	Leveled by tapping with fingers	Smoothed and curved	Leveled by tapping with fingers
M	10.3 [a]	10.5	0.5	0.6	0.11	0.15
I	14.2	14.3	0.4	0.1	0.09	0.08
J	17.1	17.4	0.6	0.4	0.15	0.08
H	21.3	21.3	0.6	0.7	0.15	0.15
A	23.0	23.0	0.4	0.3	0.11	0.06
F [b]	28.7	28.8	0.7	0.5	0.19	0.11
C	31.7	31.6	1.8	0.5	0.16	0.10

[a] The moisture equivalents are the averages of 8 samples. The samples of each soil were run in the same centrifuge set.

[b] F and C soils were machine-ground.

Wetting the Samples

Two methods of wetting the samples previous to centrifuging were tried. The centrifuge cups were placed on a layer of filter paper in the cake tin previously described and just enough distilled water was poured on to the filter paper to wet the bottom of the soil columns in the cups. The moisture soon appeared on the surface of the soil and the cups were protected from evaporation and were allowed to stand for 24 hours. This is the usual method in most laboratories and will be referred to as wetting from below. Some workers (4) wet the soil from below and remove the cups from the water placing them on blotting paper. They are covered over to prevent evaporation, and allowed to temper for 18 hours. In the procedure recommended by Briggs and McLane (2), "the soils, after being introduced into the cups, are thoroughly moistened (not saturated) without stirring, and are allowed to stand protected from evaporation for about 24 hours."

The other method tried in this investigation was to cover the soil in the centrifuge cups completely with distilled water and allow them to stand for 24 hours. The results of these two methods, that of wetting from below and saturating or completely submerging the samples, are given in Table 13. The difference between the moisture equivalents determined in these two ways is not significant. However, the variations in the moisture equivalents of samples of the same soil obtained by submerging the samples were in the majority of cases less than those obtained

by wetting from below. The method of completely submerging the samples was used throughout this investigation since it avoided the possibility of not thoroughly wetting the sample, and this treatment does not seem to affect the moisture equivalent.

TABLE 13.—Moisture equivalents of soils wet from below and of soils completely submerged. In both cases the soils were wet for 24 hours before centrifuging

Soil	Wet from below and centrifuged in sets					Completely submerged and centrifuged in sets					Difference in averages
	1	2	3	4	Average	1	2	3	4	Average	
E	4.4[a] ±0.03	4.7 ±0.04	4.4 ±0.04	4.7 ±0.04	4.5 ±0.08	4.7 ±0.05	4.7 ±0.02	4.6 ±0.04	4.6 ±0.05	4.7 ±0.08	0.2 ±0.11
B	17.8 ±0.07	17.0 ±0.08	17.4 ±0.05	17.2 ±0.07	17.3 ±0.13	18.1 ±0.01	17.7 ±0.07	17.7 ±0.08	17.8 ±0.05	17.8 ±0.11	0.5 ±0.17
A	22.9 ±0.06	22.5 ±0.07	22.6 ±0.07	23.8 ±0.07	23.0 ±0.11	22.9 ±0.04	23.3 ±0.03	23.0 ±0.04	24.0 ±0.06	23.3 ±0.09	0.3 ±0.14
F	27.3 ±0.21	26.6 ±0.13	27.3 ±0.09	26.0 ±0.15	26.8 ±0.31	27.2 ±0.31	27.1 ±0.17	27.4 ±0.34	26.6 ±0.14	27.1 ±0.32	0.3 ±0.44
C	30.0 ±0.10	30.1 ±0.13	30.2 ±0.08	30.3 ±0.09	30.1 ±0.20	30.1 ±0.09	30.4 ±0.07	30.7 ±0.12	30.3 ±0.06	30.4 ±0.17	0.3 ±0.26

[a] The moisture equivalents are the averages of 8 samples. All of these soils were pulverized with mortar and pestle.

The time during which the soil is kept moistened before centrifuging has been shown (7) to affect the moisture equivalent of a loam soil. The duration of wetting in these previous tests was from 2 to 24 hours, and the soils were wet from below. The variations in the moisture equivalents of 6 soils completely submerged for periods ranging from 2 to 196 hours before centrifuging are shown in Table 14. In general the moisture equivalents increased with increased duration of the period of saturation. The differences in the moisture equivalents of samples saturated for 9 to 12 hours and for 24 hours respectively is very slight and the difference between a 24 hour period and one of from 46 to 54 hours is also small.

Eight samples of 5 of the soils used in the previous test (Table 14) were saturated for long periods, and were then centrifuged. Four of these samples of each soil were dried to determine the amount of water retained and the other 4 were allowed to air-dry without removing them from the centrifuge cups. These 4 air-dried samples were then saturated for 24 hours, centrifuged again, and moisture equivalents were determined. The results of these determinations are given in Table 15, together with the moisture equivalents of samples of the same soils treated in the usual way.

These data show that there are significant differences between the

TABLE 14.—Moisture equivalents of soils saturated for different periods previous to centrifuging

Time of saturating	Soils					
	I	J	H	F [a]	D	C
Hours						
2 to 3	13.4 [b]	16.8	21.3		30.0	
5 to 6	13.7	16.9	21.3		30.1	
9 to 12	13.3	17.0	21.4		30.2	
24	13.4	16.9	21.9	30.0	30.4	31.2
49 to 54	14.1	17.4	22.0	30.5	31.2	
60 to 72				30.9		32.6
94 to 99	14.0	17.6	22.3		31.2	
125				31.3		33.2
191 to 196	14.1	18.0	22.9		31.8	

[a] F and C soils were machine-ground.

[b] The moisture equivalents are the averages of 4 samples of each soil, but not all of the samples of each soil were run in the same centrifuge set.

moisture equivalents of the samples saturated for long periods and those which had previously been saturated for the same periods and then air-dried. Air-drying the saturated samples resulted in smaller moisture equivalents which approached the values of samples which were saturated for only 24 hours as usual. The differences between the moisture equiva-

TABLE 15.—Moisture equivalents of soils saturated for different periods and the moisture equivalents of samples of same soils which were saturated for the same periods, centrifuged, air-dried, saturated again for 24 hours and moisture equivalent determinations made. The moisture equivalents of air-dried samples of same soils saturated for 24 hours are also given

Soil	Period of saturation	Moisture equivalents	Samples saturated, centrifuged, air-dried and moisture equivalents again determined	Air-dried samples, saturated for 24 hours, and moisture equivalents made
	Hours			
I	196	14.1 [a]	12.7	13.4
J	196	18.1	16.7	16.9
H	191	22.9	21.1	21.9
F [b]	125	31.3	27.1	30.0
C	125	33.2	30.3	31.2

[a] Each moisture equivalent is the average of 4 samples. Samples of each soil for determinations in columns 3 and 5 were run in the same centrifuge set.

[b] F and C soils were machine-ground, other soils were sieved.

lents of the samples subjected to the two last mentioned treatments are insignificant in the case of soils I, J and H, while this is not the case with soils F and C, as can be seen by comparing columns 4 and 5 of Table 15. The F and C soils used in this test were machine-ground. The moisture equivalent of the air-dried sieved soil F is 26.7 and that of the air-dried sieved soil C is 30.2. These two values are very close to the moisture equivalents of these soils given in column 4 of Table 15. This suggests that saturating machine-ground samples for long periods and then air-drying them causes the soils to be restored to a condition corresponding to unground samples in so far as the moisture equivalent is concerned. It also seems that air-drying the samples saturated for long periods give moisture equivalents about the same as the samples saturated for 24 hours.

Puddling Saturated Samples Before Centrifuging

The effect on the moisture equivalent of puddling saturated samples were studied with 6 soils. Eight samples of each soil were saturated for 24 hours. Four of these were stirred with a glass rod before centrifuging while the other 4 were treated in the usual way. The stirring was very vigorous and an attempt was made to puddle the soils thoroughly. The results of this test are given in Table 16. While the moisture equivalents of all of the puddled soils were higher than those which were not puddled, the differences are less than such severe treatment would suggest. This is especially surprising in connection with soil C, the Yolo clay, in which the difference in moisture equivalent of puddled and normal samples is insignificant. These results seem to indicate that no unusual precaution need be taken to guard against jarring the samples while they are saturated. In fact, a test was made of samples of 4 soils treated in the usual way and by vigorously striking the cups containing saturated samples of the same soils, and no significant differences were obtained.

TABLE 16.—Moisture equivalents of soils which were puddled by stirring the saturated samples previous to centrifuging and of soils treated in the usual way

Treatment	Soils					
	K	J	H	F	D	C
Puddled	12.7[a]	18.1	22.1	29.7	32.0	31.8
Non-puddled	11.9	17.5	21.2	28.6	30.7	31.6

[a] Each moisture equivalent is the average of 4 samples. The puddled and non-puddled samples of each soil were run in the same centrifuge set.

The Temperature During Saturating and Centrifuging

During these investigations differences in moisture equivalents were noted which were thought might be attributed to differences in tempera-

ture during the time of centrifuging and of storage of the saturated samples. The results of storing the saturated samples at different temperatures for the 24 hour period previous to centrifuging are given in Table 17. The soils were allowed to come into equilibrium with the air temperature before centrifuging. The moisture equivalents increased with the increase in temperature during the period of saturation when the air temperature during centrifuging remained the same. The differences between samples saturated at 1.5 and 36.5° C. for the 3 soils tested are just about significant.

TABLE 17.—Moisture equivalents of soils stored at different temperatures during the saturation period previous to centrifuging

Temperature of air during saturation	Soils		
	I	A	D
°C.			
1.5	13.1[a]	22.4	30.5
23.0	13.6	22.9	31.1
36.5	13.8	23.4	31.6
65.0	14.3	23.8	31.9
Temperature of soil just before centrifuging	20.5	19.0	18.0
Temperature of air during centrifuging	20.5	20.5	19.0

[a] Each moisture equivalent is the average of 4 samples. The samples of each soil were run in the same centrifuge set.

This effect of temperature differences during saturation and centrifuging is further evidenced by the data in Table 18. The saturated samples stored at 1 to 13° C. had slightly larger moisture equivalents when centrifuged at 10° C. than those centrifuged at about 41° C. Samples stored at 37° C. gave larger values when centrifuged at 11° C. than those centrifuged at 36° C. The moisture equivalents of soils I, A, and D stored at a temperature varying from 21 to 26° C. and centrifuged at about 25° C. agree with the moisture equivalents of the same soils given in Table 17 for storage at 23° C. and centrifuging at about 20° C. The variations in moisture equivalents due to temperature differences during centrifuging are slight for the usual ranges in temperatures, and about equal to the amounts Briggs and McLane (2) predicted. However, the fact that temperature differences during storage of the samples also influences the results suggests that attention should be given to temperature if close comparisons are desired.

Balanced and Unbalanced Loads

The moisture equivalents of samples placed in the centrifuge so that the load was carefully balanced, and of samples of the same soils which were

TABLE 18.—Moisture equivalents of saturated soils stored and centrifuged at different temperatures

Temperature during saturation	Temperature of soil just before centrifuging	Temperature of air during centrifuging	Soils			
			I	G	A	D
°C.	°C.	°C.				
4.5 to 13	10	10	13.2[a]	16.6	22.2	30.6
4.5 to 13	11	10	13.2	16.7	22.4	30.4
Average			13.2	16.6	22.3	30.5
1 to 10	37.5	41	12.6	15.9	22.3	30.3
1 to 10	36.5	42	12.6	16.6	22.0	30.1
Average			12.6	16.3	22.1	30.2
37	8.5	11	14.2	17.6	23.5	31.6
37	8.0	11	14.2	17.9	23.4	31.5
Average			14.2	17.8	23.4	31.5
37	35	36.5	13.4	16.9	22.5	30.3
37	36	36	13.3	16.9	22.3	30.6
Average			13.3	16.9	22.4	30.4
21 to 26	24	25.5	13.5	17.1	22.8	31.0
21 to 26	23	25	13.5	17.2	22.9	31.2
Average			13.5	17.2	22.8	31.1

[a] Each moisture equivalent is the average of 4 samples run in the same centrifuge set.

run with very unbalanced loads are given in Table 19. The loads were unbalanced to greater extent than would probably occur under usual conditions. Nevertheless, the moisture equivalents agreed with those centrifuged in balanced loads. However, the speed of the centrifuge was held in both cases very close to 2440 r.p.m. during the tests. In further

TABLE 19.—Moisture equivalents of samples of soils run in carefully balanced centrifuge loads and those in greatly unbalanced loads with but speed constant

Soil	Balanced load	Unbalanced load
B[a]	17.6[b]	17.6
A[a]	23.6	23.7
C[a]	30.3	30.0
C Machine-ground	31.6	31.5

[a] These soils were pulverized with mortar and pestle.

[b] Each moisture equivalent in column 2 is the average of 12 samples and each one in column 3 is the average of 8 samples. The samples were run in sets of 4 each.

tests with balanced and unbalanced loads when the speed was allowed to vary, differences were obtained which were about the same magnitude as those reported by Russell and Burr (4) for the same variations in speed.

DRYING CENTRIFUGED SAMPLES

Variations in the oven-dried weight were observed when centrifuged samples of the same soil were put in different places in the oven. The results of further tests on the effect of the temperature of drying on the moisture equivalent are given in Table 20.

TABLE 20.—Oven-dried weights of centrifuged samples when dried at different temperatures in an electric oven

Temperatures during drying	Soils			
	K	J	H	D
°C.				
95 to 103	11.7[a]	17.3	21.8	31.0
105 to 112	11.5	17.2	21.7	30.8
98 to 150	11.8	17.5	22.1	31.6
155 to 180	12.0	18.1	22.3	32.0

[a] Each value is the average of 4 samples run in the same centrifuge set.

The samples were placed on one shelf in the oven and the temperature was read at frequent intervals by means of 3 thermometers supported close to the small cans containing the samples. The thermometers could be read through a window in the door of the oven without opening the door. The temperatures in column 1 of Table 20 give the extremes recorded during the 48 hours the samples were dried. All of the soils showed larger moisture equivalents when the temperature of the oven increased to about 150° C. but the differences in any case probably are not significant. It would seem that variations from 103 to 150° would not materially affect the moisture equivalent. The soils used in this test were not rich in organic matter. Probably greater differences would have been obtained in the samples dried at the higher temperature with soils rich in organic matter.

Four sets of samples (64 in all) of each of 3 soils were centrifuged. Eight samples from each set were dried in a vacuum chamber in an electric oven and the other 8 samples were dried in an electric oven at normal pressure. In both cases the temperature was held at about 110° C. The average moisture equivalents of the 32 samples of each soil dried in the vacuum chamber and of the 32 samples dried under normal pressure are given in Table 21. The differences in the average moisture equivalents are not significant. The variations in the samples dried in

the vacuum chamber were less than those dried at normal pressure, as is evidenced by the smaller probable errors. The results obtained by drying at normal pressure are probably sufficiently accurate for moisture equivalent determinations.

TABLE 21.—Moisture equivalents of centrifuged soils dried in an electric oven in a vacuum chamber and at atmospheric pressure

Soil	Dried in vacuum chamber	Dried at atmospheric pressure	Difference
A	24.5[a]±0.07	24.1±0.21	0.4±0.23
C	31.6±0.08	31.5±0.16	0.1±0.18
F	30.8±0.10	30.1±0.20	0.7±0.23

[a] Each moisture equivalent is the average of 32 samples. Sixteen samples of each soil were run in the same centrifuge set and 8 were dried in vacuum and 8 at atmospheric pressure.

DISCUSSION AND SUMMARY

Although Briggs and McLane (1, 2) clearly described the procedure to be used in making the moisture equivalents considerable differences in the technique occur in difference laboratories. Clearly there is need for further standardization of the method.

Concordant results have been obtained when the selection of the samples for centrifuging has been by weight if other precautions were also observed. It has been shown (3, 6, 7) that the thickness of soil layer in the centrifuge cup does affect the moisture equivalent. While the depth of centrifuged soil layer is of considerable importance from theoretical considerations it is doubtful whether, in the use of the moisture equivalent method, the depth of layer need be vigorously controlled. The determination by weight of the amount of soil to use for centrifuging will result in different thicknesses of layers with different soils. In the present investigations variations in thicknesses of layers of centrifuged soils were from 7.76 mm. to 10.27 mm. when 30 g. samples of soil were used (see Table 3). Thomas (6) has stated that increasing the size of samples reduces to a slight extent the amount of water retained in very coarse and very fine soils, but that the effect is greater for soils of intermediate texture. It has been noted by the writers that the thickness of the centrifuged samples of some soils, especially heavy soils or those containing a large amount of organic matter, is much greater than the thickness of the same samples in the air-dried condition. This is due to the swelling of the soil during saturation. Either the weight or the volume method of selecting the samples would fail to give thicknesses of layers of centrifuged samples of such samples which were the same as those of other soils.

The thickness of soil layer cannot be determined in advance of centri-

fuging and the volume of soil to use must be determined by trial for each soil if the same thickness of layer is prescribed for all soils. The same

TABLE 22.—Moisture equivalent determinations and variations in the results of 20 samples centrifuged in 5 sets of 4 samples each

Soil	Average of 20 samples	Probable error of mean	Probable error of a single determination	Maximum difference between: Average of any 4 samples in same set and average of 20 samples	Any 2 averages of sets of 4 samples	Any 2 samples out of 20	Any single sample and the average of 20
Z	2.58	0.009	0.039	0.04	0.08	0.14	0.13
N	3.29	.022	.093	.14	.25	.50	.25
E	4.51	.018	.081	.15	.27	1.05	.82
U	6.05	.036	.162	.22	.44	.59	.32
AL [a]	7.52	.033	.134	.13	.21	.82	.62
M	10.52	.028	.125	.17	.32	.75	.42
K	11.44	.031	.138	.28	.45	.80	.40
I	13.02	.033	.146	.12	.30	.76	.48
TL [a]	13.71	.021	.084	.07	.13	.40	.22
B	16.20	.041	.183	.28	.53	.80	.47
G	16.91	.035	.151	.19	.34	.77	.40
J	17.07	.017	.077	.11	.15	.44	.30
X	17.28	.056	.252	.39	.69	1.45	.83
TC	17.30	.044	.199	.43	.74	1.57	.94
P	18.49	.054	.234	.38	.74	1.50	.79
W	18.79	.052	.234	.32	.61	1.36	.79
L	18.91	.059	.264	.34	.57	1.41	.80
H [a]	21.32	.036	.142	.19	.23	.62	.50
S	21.35	.043	.193	.27	.45	1.18	.70
R	22.26	.039	.171	.23	.35	.81	.44
A	22.49	.036	.162	.32	.61	.95	.56
O	27.33	.049	.218	.35	.73	2.07	1.07
F [b]	28.39	.056	.238	.57	.76	.93	.70
Q	28.66	.043	.189	.22	.43	1.18	.65
GC [a]	30.42	.033	.132	.21	.38	.82	.42
D	30.61	.048	.208	.37	.65	1.05	.66
C [b]	31.42	.026	.113	.19	.25	.50	.25
V	37.90	.067	.301	.52	.98	1.78	1.30

[a] Values for these soils are based on 16 samples only.
[b] F and C soils were machine-ground.

volume of all soils will not always give the same thickness of layer of centrifuged soil. The variations which might occur by selecting the sample by volume have not been studied in the present investigation.

Moisture equivalents made on samples stored in a moist condition may be different from moisture equivalents made on air-dried samples of the same soils, but air-drying the moist samples seems to restore the soil to a condition which gives about the same moisture equivalents as the original air-dried samples.

Cropping and repeatedly wetting the soil did not produce changes in the soils which affected the moisture equivalent if the soils were air-dried previous to preparing the samples for centrifuging. The removal of roots from the cropped soil did not affect the moisture equivalent and this suggests that no special effort need be taken to remove the smaller roots from the samples in preparing them for centrifuging.

It is clear from the preceding statement that the previous history of the soil in the field under usual conditions of moisture changes and cropping does not change the soil in so far as the moisture equivalent is concerned, provided the samples are air-dried previous to making the determination.

Machine grinding and pulverizing the samples with mortar and pestle and by rolling give different moisture equivalents than those obtained when the lumps of soil were crumbled and forced through the sieve with the fingers. Preparing the samples for centrifuging with mortar and pestle and with rubber roller gave variable results when the samples were prepared by different operators. Standardizing a method of preparing the samples by machine grinding seems to be impracticable. The kind of grinding burrs used and their distance apart, the operating speed of the machine, the rate at which the soil is fed into the machine, and other conditions affect the result. Concordant results were obtained when the samples were prepared by crumbling the lumps of soil with the fingers alone, and forcing the soil through the sieve with the pressure of the fingers.

Moisture equivalent determinations were made on 28 soils, after all the precautions found in this investigation to be necessary were taken, and are reported in Table 22. This table shows the degree of accuracy which may be expected in moisture equivalent determinations when they are made with extreme care. It is clear that the moisture equivalent when properly made may be used with confidence.

The results obtained in this investigation have led to the adoption of a procedure for determining moisture equivalents which the writers have found gives concordant results. This procedure is essentially the same as that outlined in the beginning of this paper. The points to be emphasized are as follows:

1. Moisture equivalents to be made on air-dried samples only.
2. Soil to be crumbled and forced through a 2 mm. sieve with fingers only. Large lumps may be broken by mechanical means if care is taken not to pulverize the soil.
3. No special care need be taken to smooth the surface of the soil in the cups. Tapping the cups lightly to level the surface of the soil gives satisfactory results.
4. For usual purposes samples may either be wet from below or completely submerged.

5. Samples should be saturated for 24 hours but this period may be shortened or lengthened safely, at least, by 3 or 4 hours.
6. Temperature during saturation, as well as during centrifuging, to be about 20° C.
7. No special care need be taken to balance the load in the centrifuge if the proper speed is maintained.

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THE SUCTION FORCE OF SOILS AND ITS DEMONSTRATION IN THE PLANT HABITAT

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Movement of water in the soil is considered due in part at least to action of molecular forces in soil colloids which give rise to a "suction force." This force has been measured (2) by a mercury manometer attached to a porous clay candle system. A porous clay cup is filled with distilled water, immersed in soil and a mercury manometer is attached. As water passes from cup to soil a partial vacuum results and mercury is drawn up the glass tube of the manometer.

With care taken to insure air-tight joints the system works excellently. Its chief drawback is that the force measured is due only in part to soil colloids, for ultimately passage of water from clay candle into soil is governed by evaporation into air from the exposed soil surface, and the evaporating power of the air varies. This is evidenced by exposing two experiments to identical conditions except that one has the soil covered with paraffin while the other is freely exposed to the air. In the first case there is a certain rise of mercury in the manometer beyond which no further "suction" is evident (that is, the soil has taken up all the water which it can by capillarity); in the second case there is a steady rise of mercury until water in the cup is exhausted. This rise is more rapid in the laboratory where loosely granular soils is used and the air is drier. In the field action is frequently slow, showing once again the difference between field and laboratory experiments.

While studying ecological factors operating in New Jersey pine barrens a body of data was collected which seemed to have some bearing on the "suction force" idea.

The area studied lies in Middlesex County, New Jersey, near the village of Spotswood, and is at the north-western edge of the pine barren area. Five distinct terrestrial habitats may be distinguished of which the two extremes are Red Maple Swamp and *Hudsonia* covered sands. The swamp occupies flood plains of streams and has a soil consisting of a few cm. of mycorhizal humus above a reddish peaty subsoil which has 15.7 per cent clay[1] content. The (Sassafras) sand is a light sand upon a brownish sandy subsoil, and has a clay content of 0.1 per cent.

[1] For this and the next analysis, I am indebted to Professor A. W. Blair, Soil Chemist of the New Jersey Agricultural Experiment Station.

The red maple swamp is mesophytic with a broad leaved forest growth, some undershrub, a ground cover of herbs, and there are occasional sphagnum bogs. The sands are sparsely covered with *Hudsonia tomentosa*, Poverty grass (*Aristida purpurascens*), spurge (*Euphorbia Ipecacuanhue*), sandwort (*Arenaria Caroliniana*) and a few others.

If a soil contains considerable colloids and colloids aid in passage of water through the soil, then in a clay soil there should be a more rapid

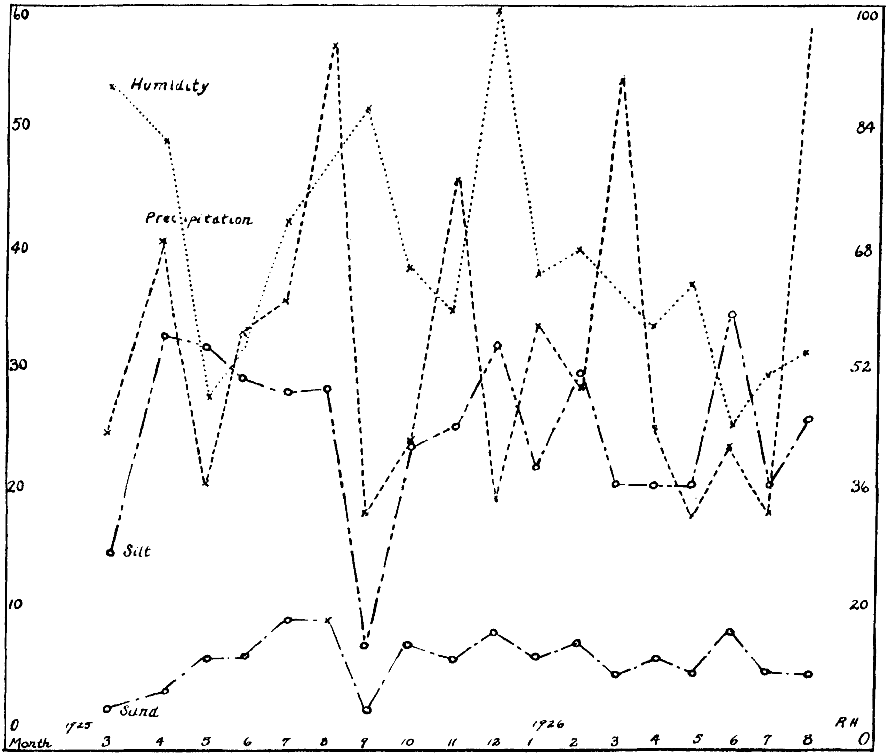

FIGURE 1.—Soil moisture, precipitation and relative humidity in Spotswood area. Figures on left of graph represent moisture in per cent, and ten times the precipitation (thus 30=3.0 in.)

passage of water and a higher moisture content than in sand without colloid material. Further, in dry weather (when relative humidity is low) there would be a greater evaporation from soil surface and hence greater suction force with consequent increase of soil moisture. Whitney and Hosmer (3) expressed the same idea in 1897.

It is seen from Fig. 1 that the silt soil has a greater moisture content than the sand, remaining between 20 and 30 per cent by weight of soil,

but in general the evaporating power of the air does not seem to have markedly affected the soil moisture content.

The curves would be changed doubtless by daily readings but it is evident that all of the curves are of the same order. The "precipitation" figures are taken from the reports of the New York Meterological Observatory and are the total for the preceding month; the relative humidity figures are from the writer's observations made with a sling psychrometer and averaged for the two habitats.

Experiments were next made directly in the field with clay cups[1] sunk in the soil with as little disturbance of the habitat as possible. Atmospheric humidity was measured in both habitats and found to differ less than was expected, probably due to the sparsity of undergrowth in the maple forest. Soil samples were taken from both habitats and measured for holard.

Results quickly showed the complexity of factors operating. In general, the manometer of the sand apparatus exhibited a quick rise to an average height of 4.38 cm. while that in the silt showed a slow rise to an average of 6.26 cm. (12 readings). These results are similar to those recorded by Garola and Chartres (1).

As far as the data was recorded there does not seem to be an inverse ratio relation of atmospheric humidity to soil moisture in the surface layers, except as the humidity is connected with actual precipitation; there does not seem to be an increase of soil moisture (taking the soil for a year) with lowered humidity. There does seem to be a direct ratio.

When the sand and silt soils were taken into the laboratory it was found that the readings varied with the air humidity as evaporation proceeds from the exposed soil surface so that readings are not always the same even when the soils are carefully dried and tested again. In general the silt soil showed a capillary force of approximately four times that of the sand.

We may conclude, then, that in the plant habitat soil moisture is directly dependent upon rainfall which is conserved by the forest canopy and leaf litter. Both the canopy and the litter aid in giving a somewhat greater humidity to the air, but atmospheric humidity does not seem to have any marked influence in decreasing or increasing the soil moisture content through "suction force" action in the field. In the laboratory, samples isolated from other factors indicate that passage of water through the soil is directly dependent on atmospheric humidity, and apparently on soil texture. It seems possible that "suction force" may be explained entirely by capillarity without reference to soil colloids.

[1] The same porous cups used by Dr. Joffe were utilized; the writer is glad to acknowledge the help given by Dr. Joffe.

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SOIL TEMPERATURE RECORDS AT ARLINGTON FARM, VIRGINIA

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INTRODUCTION

In 1924 the Bureau of Soils began keeping some soil temperature records, the information being desired primarily for answering inquiries on the subject. It is believed, however, that some of the information obtained from these records is of sufficient general interest to warrant publication.

The instruments, used for obtaining soil temperatures, were 5 mercury thermometers and 2 Friez double thermographs. The recording instruments were located in a small portable shelter like those used by the United States Weather Bureau, placed 4 inches above the ground. One thermograph recorded the air temperature within the shelter and also the soil temperature at a depth of 18 inches. The second thermograph recorded the soil temperatures at depths of 1 and 6 inches. The 3 soil thermometers were hollow brass cylinders 1 inch in diameter and 6 inches long, connected to the recorders with small flexible metal tubing, and filled with an expansive liquid. The bulbs were placed 6 feet or more from the shelter in a horizontal position with their center lines 1, 6, and 18 inches respectively below the soil surface.

In the same plot, which was 12 feet square, glass tubes were placed in the soil at an angle of 45 degrees, to depths of 6, 12, 18, 36, and 72 inches respectively, and into these were lowered mercury chemical thermometers. This arrangement did not prove satisfactory and was later abandoned. Freezing and thawing of the soil eventually broke the tubing so that it was impossible to insert the thermometers. The tubes were open at the lower end and consequently were partly filled with water during the winter and spring. These thermometers were read each Monday forenoon only, when the thermograph charts were changed. The plot was on the United States Department of Agriculture's farm at Arlington, Virginia, and the soil was Chester loam. The surface of the plot was kept free from vegetation.

DAILY TEMPERATURE CYCLES

Figure 1 shows two weekly records selected as being typical of the summer and the winter conditions. These were redrawn, combined, and changed from the original curvilinear records to rectangular coördinates.

The upper or summer series of graphs record the temperature of the air and of the soil at depths of 1 and 6 inches. In order to avoid confusion the record of the soil temperature at a depth of 18 inches was omitted from the figure. The temperature at that depth was 22.6° C., at both the beginning and end of the week and varied less than one degree from the mean of 2.4° C., showing that the daily temperature wave did not penetrate the soil to a depth of 18 inches. No rain fell during the week, although nearly two inches fell during the first half of the preceding week. No sunshine record is available except that of the United States Weather Bureau about 2 miles away. The graphs indicate that under the influence of bright sunlight the soil at 1-inch depth may become warmer than the air. It also may not cool so much at night. The soil at that depth may

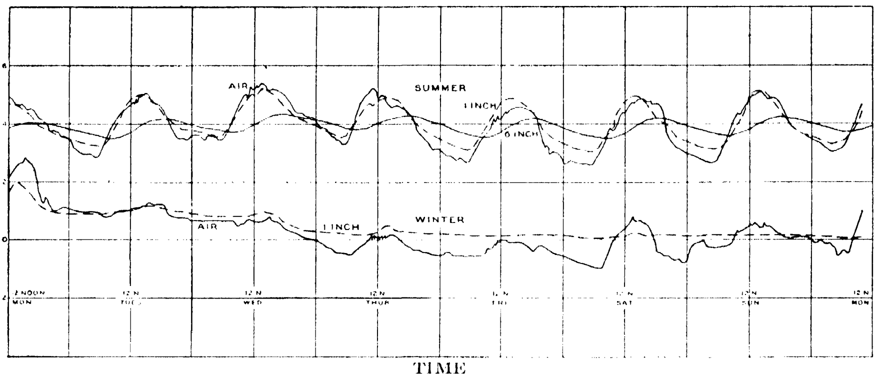

FIGURE 1.—Types of continuous records of air and soil temperatures which are made in summer and in winter

reach its maximum temperature a little sooner than the air, although their times of maximum and minimum temperatures agree rather closely. The graph of the soil temperature at a depth of 6 inches is more regular, of smaller amplitude, and reaches its peak values a few hours later. In all cases the time required for the temperature to rise is much less than the time taken for the soil to cool to its succeeding minimum. More data on this point will be presented later. The temperature change is most rapid in the air and surface soil about mid-forenoon and is slowest between 6 P.M. and 6 A.M.

The lower graphs of Fig. 1, made the first week in February are representative of winter conditions, although, of course, all types of daily temperature waves occur at all seasons of the year, except the great and rapid temperature drop known as the cold wave which is not likely to occur in summer. On Tuesday and Wednesday 0.63 inches of rain fell. To avoid confusion only the air and 1-inch soil temperatures were plotted. The 6-inch soil temperature averaged 0.4° C. higher than that at the 1-inch depth and, except on Monday afternoon, showed very little daily fluctua-

tion. The graph for the depth of 18 inches is approximately a straight line beginning at 4.6° C., and ending at 4.4° C. In contrast with the summer records these winter graphs show a much smaller daily range

TABLE 1.—Soil temperature

1924 Week beginning	Precipitation	Air	Depth 1 inch	Depth 6 inches	Depth 18 inches	Depth 72 inches
	in.	°C.	°C.	°C.	°C.	°C.
Jan. 13	1.01	3.0	3.2	3.6	4.6	9.7
20	0.81	−1.6	0.6	1.5	3.5	9.1
27		1.6	1.2	1.1	2.8	8.5
Feb. 3	0.63	2.5	3.4	3.5	4.5	8.4
10	0.09	0.8	1.8	2.2	3.1	8.1
17	2.13	−1.9	0.8	0.9	2.7	7.6
24	0.14	2.5	1.8	1.0	2.8	7.2
Mar. 2	0.09	5.7	5.3	4.3	4.9	7.1
9	2.25	3.0	3.2	2.8	4.6	7.3
16	1.68	5.2	3.9	3.2	4.7	7.5
23	1.45	9.6	8.6	6.9	6.6	7.9
30	0.73	7.5	7.3	6.6	7.2	8.5
Apr. 6	2.42	9.6	9.2	8.2	8.3	9.0
13	1.48	12.5	11.7	10.6	10.1	9.5
20	0.12	12.4	11.1	9.9	10.2	10.2
27	0.51	14.3	13.4	12.0	11.6	10.9
May 4	1.65	16.8	16.4	14.7	13.5	11.7
11	2.51	14.5	14.7	13.6	13.5	12.2
18	0.86	16.3	16.0	14.8	14.2	12.7
25	1.57	16.1	16.3	15.4	15.0	13.5
June 1	0.61	19.1	18.8	17.1	16.1	14.6
8	1.94	18.8	19.0	18.0	17.1	15.7
15	0.35	25.1	25.1	22.6	17.5	16.7
22	0.34	24.3	25.7	23.2	21.8	17.7
29	0.18	22.3	22.8	21.8	21.0	18.2
July 6	1.92	24.6	24.5	23.1	21.8	18.7
13	0.05	23.9	24.5	23.4	22.4	19.5
20	0.04	25.6	26.1	24.5	23.1	20.0
27		24.3	26.2	24.8	23.6	20.5
Aug. 3	0.43	26.6	27.1	25.3	23.8	20.7
10	2.97	22.3	23.2	23.1	22.9	20.6
17	0.80	21.4	22.0	22.3	21.3	20.9
24	1.81	23.3	23.5	22.4	21.9	20.6
31	0.61	20.6	19.9	20.7	21.5	20.0
Sept. 7	0.17	17.9	18.1	18.4	18.7	19.7
14	0.71	17.3	16.9	17.5	18.0	19.0
21	1.36	16.2	16.7	16.9	17.2	18.0
28	5.20	14.5	14.8	14.8	15.7	17.4
Oct. 5		15.0	15.4	15.6	15.9	16.5
12		13.5	13.4	13.6	14.5	16.0
19		10.2	11.2	12.2	13.3	15.8
26	0.75	12.4	12.4	12.9	12.9	15.5
Nov. 2	0.09	11.2	11.0	11.8	12.2	14.9
9		8.3	9.7	10.0	11.5	14.0
16	1.47	1.9	4.0	5.0	8.0	13.1
23	0.03	2.7	3.7	4.3	7.2	12.2
30	0.58	1.5	1.5	2.8	5.2	11.6
Dec. 7	1.52	4.0	5.5	5.3	7.1	10.7
14	0.02	3.8	3.8	3.8	6.1	10.3
21	0.52	−5.3	−0.8	0.1	3.9	
28	1.09	−3.1	−0.9	−0.8	2.5	
Jan. 4		−1.1	−0.1	−0.1	2.7	

without regular and well marked maxima and minima. Russell and Keen (1) found similar relationships between the winter and summer soil temperatures at Rothamsted.

THE ANNUAL TEMPERATURE CYCLE

Table 1 gives a series of average weekly temperatures for the 52 weeks beginning January 13, 1924. The air, and the 1-inch, 6-inch and 18-inch soil temperatures are taken from the continuous thermograph records. The 72-inch temperature was obtained from a mercury thermometer read only once each week. At this depth the temperature changes are so slow that this value is approximately the average temperature for the week. The total weekly precipitation, which is included in the table, shows a well distributed rainfall in the spring with a dry July, and a longer rainless

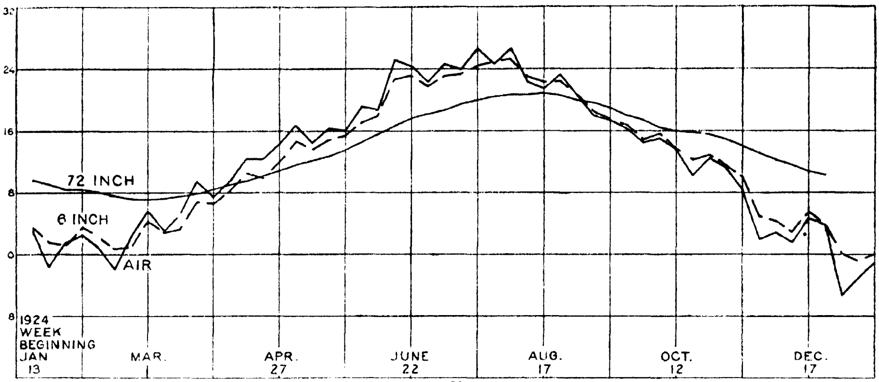

FIGURE 2.—Average weekly air and soil temperatures

period, in October and November. The average weekly temperature range for the air varied from −5.3° C., in December to 26.6° C., in August. For the 1-inch soil depth the annual temperature range was from −0.9° to 27.1°; for the 6-inch depth it was from −0.8° to 25.3°; for the 18-inch depth, from 2.5° to 23.8°; and for the 72-inch depth, from 7.1° to 20.9°. The annual amplitudes of the weekly averages were 31.9, 28.0, 26.1, 21.3, and 14.8° C., respectively.

The weekly average values of the air, 6-inch and 72-inch soil temperatures are shown graphically in Fig. 2. The 1-inch and 6-inch soil temperatures were omitted to avoid the confusion of intersecting graphs. The soil at 72 inches deep, reached its minimum temperature about the first of March and its maximum the middle of August. This is about 2 weeks later than the corresponding temperatures 6 inches below the surface were recorded. The period of rise was about 24 weeks, making the first half of the annual cycle shorter than the second half. From the last of February to the middle of August the weekly air temperature exceeded that of the

soil at a depth of 6 inches. For the remainder of the year the soil was generally the warmer. Corresponding temperature changes for the air and soil at the 72-inch depth took place about a month later. The average weekly temperature of the surface soil followed that of the air more closely, but generally was slightly lower than the air temperature in the spring, and higher in summer.

AVERAGE DAILY TEMPERATURE RANGE

From the air, 1-inch, and 6-inch charts the daily minima and maxima were tabulated and combined into weekly averages. While in general the minima occurred in the morning and the maxima in the early afternoon in regular order, they sometimes occurred in reverse order and at times the

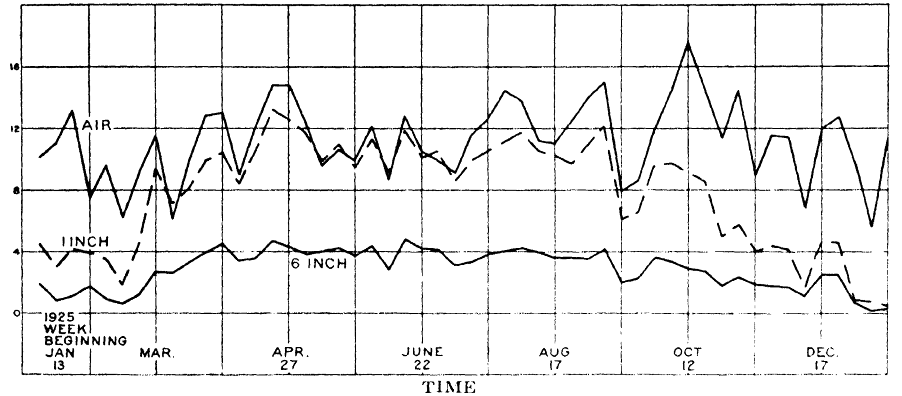

FIGURE 3.—Weekly average values of the daily temperature range of air and soil

minimum of one day was the maximum of the next and vice versa. In Fig. 3 these weekly averages were plotted and, in order to make indentification easier, were joined to form a continuous graph. The average annual daily temperature range was 11.2, 7.7, and 2.8° C., respectively for the air, 1-inch, and 6-inch soil.

While in late spring and summer the soil at a depth of 1 inch had nearly as large an average daily amplitude as the air, in the late fall and winter the range was very much less. From the character of the graphs in Fig. 1, this would be expected. From Fig. 1 one would also expect that the same would be true of the daily air temperature range, but Fig. 3 shows no such marked difference. Although there were, of course, many exceptions to the most common type of summer and winter graphs shown in Fig. 1, there were, in addition, rather frequent cold waves in winter when the temperature fell continuously during nearly the whole 24 hours. Such large drops in temperature with the later recovery helped to maintain a rather large average daily temperature range during the winter season.

shows the weekly average of the daily temperature range for the air and for the soil 3 inches deep, both shaded and unshaded, for the 52-week period beginning August 2, 1925. These graphs show that shading has a marked effect on the daily range except in winter; and that while the daily amplitude increases in summer, it does not increase so much as it does in the unshaded soil.

The time of day at which the normal daily temperature cycles reached their maximum and minimum temperatures was tabulated for each month, with results consistent with those given in Table 2. The bare and shaded soils reached their average annual minima at 6.8 A.M. and 7.5 A.M. and their average annual maxima at 2.7 P.M. and 3.8 P.M. respectively. The time of day at which the maximum temperature occurred showed no seasonal variation, but the time of day at which the average minimum temperature occurred was earlier in summer than in winter, just as in Table 2 of the previous records of unshaded soil.

SUMMARY

Continuous temperature records of the air and of the soil at depths of 1, 6, and 18 inches were made at Arlington Farm, Virginia, and their weekly averages, together with these of a mercury thermometer at a depth of 72 inches in the soil, were tabulated for the 52-week period beginning January 13, 1924. In the annual temperature cycles, the soil at 72 inches reached its minimum about the first of March and its maximum about the middle of August, and the soil at 6 inches reached corresponding values about 2 weeks earlier. From the last of March until the first of September the air was warmer than the soil at 72 inches, the corresponding changes between the air and soil at 6 inches occurring a month earlier. The daily temperature cycle had a larger and more regular amplitude in summer than in winter. The daily temperature wave penetrated the soil more than 6 inches but less than 18 inches. The time of day at which both air and soil reached their maxima in temperature showed no seasonal variation, but the time of day at which they reached their minima varied with the time of sunrise. Average daily maxima and minima at a depth of 6 inches in the soil occurred about 4 hours later than the average daily maxima and minima for the air. Temperature records of shaded and unshaded soil at a depth of 3 inches showed that the shaded soil had about the same temperature as would obtain in an unshaded soil at 1 or 2 inches greater depth

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SOIL COLLOIDS AND THE TEXTURAL CLASSIFICATION OF SOILS

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Soil colloids have been the object of study to a greater or less extent by members of the Soils Section of the Michigan Agricultural Experiment Station for the last 10 years. These studies were initiated because colloids were considered to play various and important rôles with respect to soil characteristics, and they have been continued for the same reasons.

It appears that the amount of colloids present in most soils is greater than has been believed heretofore, and it also seems that they do not always exist as coatings around other particles. It is rather difficult to conceive of such being the case where the greater part of a soil consists of colloids. On the other hand the indications are that they do occur mainly as coatings in the *B* horizons of the strongly podsolized sandy soils.

It is obvious that the reactivity of the soil colloids and likewise their influence upon soil characteristics differ appreciably. It has been shown, for example, the heat of wetting of soils when brought into contact with different liquids, such as water, nitro-benzole and alcohol varies greatly. In a given profile there may be horizons that respond differently to a given liquid and to different liquids.

Additional evidence has been obtained by dispersing colloids and collecting them on the tube of a Sharples Supercentrifuge. They were roughly separated into three groups by varying the rate at which the liquid was allowed to pass through the centrifuge and by separating the mass that collected on the tube. Wide variations exist in the heat of wetting values, color and also in the tenacity of the materials collected at or near the base of the supercentrifuge and those higher up. Usually the former prove to be easily pulverized when dry and the latter much more tenacious and horny-like in nature. The heat of wetting values of the former (Group 1) are much lower than the latter (Group 2) whereas those which comprise Group 3 (obtained only when the liquid passes through the bowl slowly) evolve the most heat when wetted with water. The majority of the mass that remained in suspension over a 24 hour period falls into Group 1. The percentage, however, is greater with some horizons than it is with others. The results are summarized in Table 1.

Colloids have been removed from various horizons of many soil types and their heat of wetting values determined. These investigations show that with the exception of the A_0 or the horizon containing the largest

TABLE 1.—Calories of heat developed per gram of material from Ontonagon soil horizons

Sample number	Calories
A_1–1	5.36
A_1–2	9.36
A_1–3	10.67
A_2–1	4.94
A_2–2	9.00
A_2–3	11.73
B_1–1	5.14
B_1–2	9.53
B_1–3	11.08

amount of organic matter, the colloids removed from the *B* horizons to be the most active. The amount of heat liberated when the colloids from the *B* horizon of the podsolized sandy soils are brought into contact with water is remarkably large. In some cases it reaches almost 20 calories per gram of material. It thus appears that the colloids that have been formed or altered, as the case may be, by weathering are more active in the soils studied than those present in the original or parent glacial material.

Some *B* horizons that have about 20 per cent of colloids are far more tenacious and less penetrable to roots of plants than are some that carry as much as 40 or 50 or even 70 per cent. They are very deceptive, as will be shown later on, when one attempts to classify them.

The amount of colloids present in more than 150 samples of soil representing sands, sandy loams, loams, silt loams, clay loams and clays have been determined by the heat of wetting and the hydrometer methods. The samples were classified in the laboratory by experienced field men. Wide variations in the colloids present in a given textural group occur. The minimum, intermediate and maximum amounts found are given in Table 2.

A glance at this table reveals that in the sandy group the percentage of colloids ranges from 5.6 to 18.3. Similar variations occur in all groups with the exception of the silty clay. It should be noted that soils which are classified as clays range from 40 to more than 87 per cent in their colloidal content.

In addition to the above studies a comparison of the amount of colloids present as determined by the hydrometer method and the silt and clay as determined by the standard mechanical analysis method has been made. Several samples were obtained through the courtesy of A. H. Joel of the University of Saskatchewan. The results are given in Table 3.

The amounts of clay reported and the colloids present as determined by the hydrometer method on the whole are surprisingly close. In some

TABLE 2.—Textural classification and colloids

Textural classification	Colloids	Textural classification	Colloids
	per cent		per cent
Loamy fine sand	5.6	Silt loam	26.0
Do	12.3	Do	33.6
Loamy sand	18.3	Do	43.0
Coarse sandy loam	11.7	Silt clay loam	30.3
Sandy loam	19.7	Do	42.0
Coarse sandy loam	30.3	Do	52.2
Very fine sandy loam	14.5	Clay loam	33.0
Fine sandy loam	21.3	Do	41.0
Do	34.5	Do	47.7
Light loam	17.7	Silty clay	50.6
Do	21.7	Do	54.0
Do	27.9	Do	56.6
Loam	21.0	Clay	40.5
Do	28.0	Do	60.3
Do	36.3	Do	87.7

instances, however, the differences are quite large. It is probably that these are due to lack of dispersion when the samples were prepared for the mechanical analysis.

A knowledge of the total amount of colloids present in soils is very desirable and it is doubtless true that this is the most important single

TABLE 3.—Silt and clay in soils in comparison with the colloids (Canadian Soils)

Soil No.	Silt	Clay	Colloids hydrometer method
	per cent	per cent	per cent
1 A	17.9	14.0	23.74
2 A	20.0	18.8	27.74
3A	25.3	8.1	25.04
4 A	35.4	16.8	31.04
4 B	17.9	32.2	39.04
1 B	14.7	33.4	45.04
3 B	16.9	20.5	27.04
333 A	10.3	10.1	17.74
333 B	5.3	8.0	13.74
333 C	5.3	11.1	15.74
343	30.6	27.9	37.04
345	31.6	56.0	67.74

physical determination that can be made. It is desirable also to know something of the reactivity of the colloids present and furthermore, if the results obtained by the standard method of mechanical analysis do not represent the true amounts of fine sand, silt and clay in all instances, it is because of incomplete dispersion of the samples when they are shaken. It is probable that the proportions of the various grain sizes called for in the textural classification now in use needs revision.

If colloids play the important rôles in governing soil characteristics that are attributed to them, it appears according to the above studies, that it is advisable for the field men to know more accurately the amount of them in the soil types they are mapping.

METHODS OF DETERMINING THE MAXIMUM MOLECULAR MOISTURE HOLDING CAPACITY OF SOILS

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On the basis of studies made in 1916 (2) on the physical properties of soil moisture the author suggested the following forms: (1) Vapor phase, (2) Hygroscopic water, (3) Film water, (4) Gravitational water, (5) Water in solid phase, (6) Crystalization water, (7) Chemically combined water.[2] At that time the idea of the "Maximum Molecular Moisture Holding Capacity" was introduced by the author. This term represents the water held between the soil particles because of the molecular forces of cohesion between the soil particles and the water. A determination of the value of this force shows not only the upper limit of the film water but also the limit above which the water of the given soil is found in a form which is influenced by the forces of gravity.

Three methods were used by the author for the determination of the maximum molecular moisture holding capacity: (1) The method of high columns, (2) Method of centrifuging, (3) Method of film equilibrium.

The method of high columns consists of the following: soil is poured into tall tubes (1 m. or more) and slightly compacted. Water is percolated into the tube under a constant water pressure. When the saturation reaches a maximum the addition of water from the top ceases and the excess water is allowed to run off. Care has to be taken to prevent the drying out of the soil at both ends of the tube. Then the moisture content of the soil is determined in the upper portion of the tube and this gives the value for the maximum molecular moisture holding capacity. It is important to point out that this value can not be determined in the uppermost layer of the soil; its moisture content is somewhat greater than the maximum molecular moisture holding capacity of the soil. The sample is taken 10 cm. below the surface. This method is very convenient and simple for sandy soils. For clay soil it is not practical, because in this case very long tubes (more than 5 m.) are necessary, and the experiment has to be continued for several months.

[1] Translated from the original Russian manuscript by J. S. Joffe, New Jersey Agr. Exp. Sta., New Brunswick, N. J.

[2] A résumé of the paper was given before the First International Congress of Soil Science.

METHOD OF CENTRIFUGING

When a very moist soil is centrifuged all of the gravitational water is driven off and the moisture left will be the maximum molecular moisture holding capacity. This method is very simple and convenient. In the earlier work reported (2) the centrifuge used had a speed equal to 400 G. This force is not sufficient for the removal of gravitational water from short columns of clay soils. The work reported below is a continuation of the study of the centrifuge method for the determination of the maximum molecular moisture holding capacity.

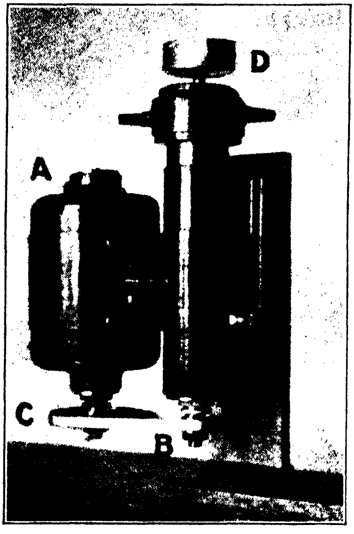

FIGURE 1.—Highspeed centrifuge ("Dumore" Multo-Speed Grinder Co.)

A represents the motor
B Do cylinder spindle
C Do pulley
D Do bowl

A centrifuge was constructed by the author which gives 50,000 revolutions per minute and develops a force of about 70,000 G. This centrifuge is a development of the one used by Dummor (Wisconsin). A 2 in. bowl, ¾ in. high, made from duralumin is placed on a spindle. Three grooves, 0.5 mm. deep, are cut in the inner side walls of the bowl, and besides 12 holes, 1.5 mm. in diameter are made in the wall. The soil to be centrifuged is placed into a little box one side of which consists of a fine sieve (0.25 to 0.5 mm.); the opposite end of the little box has a cover with a hole in the center, 0.75 mm. in diameter. The sieve on the inner side of the box is covered with filter paper. Then 0.5 to 1 g. of soil is placed into the box and slightly compacted. It is important that for each particular soil the layer should be about the same in all determinations. The soil is then moistened so that the surface of the soil layer is covered with water. The box is placed into water in such a manner that the surface of the water is 1 to 2 mm. above the surface of the soil. After 5 or 10 minutes the boxes are taken out and the sieve end is placed on filter paper. In most cases the excess of water is removed by this operation; this facilitates the process of centrifuging. Four boxes of this type are placed simultaneously into the bowl. It is desirable to have the boxes with the soil and water of uniform weight. This gives a better balance for the centrifuge. Experiments have shown that a difference in weight of the box up to 0.5 g. gives no trouble. After centrifuging the soil is highly compacted; it is taken out of the box and dried at 105° C. The amount of moisture in per cent on

the basis of the dry weight of the soil gives the maximum molecular moisture holding capacity.

THE INFLUENCE OF THE CENTRIFUGAL FORCE ON THE AMOUNT OF WATER RETAINED BY THE SOIL

In order to find a method for the determination of the maximum molecular moisture holding capacity which should be available for all soils, sandy as well as clay soils, it was important to establish the relationship between the moisture of the various soils and the forces of gravity necessary

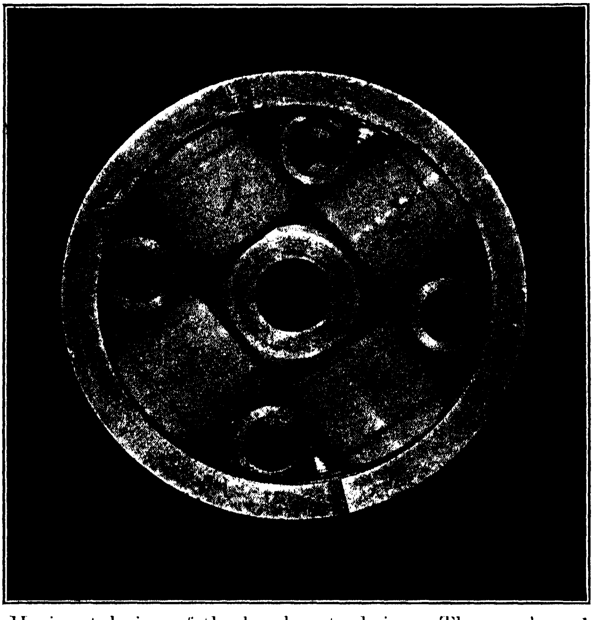

FIGURE 2.—Horizontal view of the bowl; actual size. The numbers 1, 2, 3, 4 represent the boxes which contain the soil. The circles between the boxes represent aluminum tubes which prevent the displacement of boxes during the process of centrifuging. The black in the center represents the bore for the spindle axis

to remove the gravitational water. The results of such experiments are given in Table 1. The experiments show that with the increase of the forces of gravity from 400 to 18,000 G. the moisture of all soils, clay as well as sandy, decreases; from 18,000 to 70,000 G. the moisture content remains constant. The small decrease in moisture content noticed is due to evaporation. The experiment shows therefore, that low speed centrifuges which develop less than 18,000 G. do not remove all the gravitational water from soils; on the other hand centrifuges which develop a speed higher than 18,000 G. remove the gravitational water from all soils (the soil from Brazil contains 86 per cent clay). It is interesting to note that

TABLE 1.—Relationship between forces of gravity and soil moisture in per cent. Time of centrifuging 5 minutes

Sample number	Soils	Approximate force of gravity									
		400	700	1,100	4,600	12,000	18,000	27,000	35,000	50,000	70,000
1	Clay soil	54.1	50.9	50.4	43.3	38.6	32.0	30.9	31.1	31.7	31.7
2	Guara-Kingu river, Brazil	50.8	46.1	41.5	37.8	35.2	33.4	32.1	32.6	32.4	32.4
3	Susquehanna clay loam, Va.	41.2	38.4	38.0	31.2	26.9	24.3	23.9	23.9	23.0	22.5
4	Houston clay, Miss.	40.5	38.1	35.1	27.5	25.0	23.6	24.6	23.2	23.4	23.4
5	Decatur clay loam, Ga.	32.1	29.1	24.4	20.6	18.9	18.1	17.5	17.1	17.0	16.5
6	Marshal silt loam, Neb.	34.2	32.2	31.4	23.1	17.0	14.1	14.8	14.6	14.0	13.5
7	Sassafras silt loam, Md.	21.7	21.5	20.9	13.5	8.2	6.9	6.4	6.2	6.1	5.9

in all soils, clay as well as sandy, the constant moisture content begins at the same potential of gravitational forces. The reason for this is that 18,000 G. is sufficient to remove the gravitational water from the minutest capillaries of the soil. When the centrifuge develops less than 18,000 G. the water from the larger capillaries only is removed and the lower the force of the centrifuge the less water is removed. During the process of centrifuging slight drying of the soil is noticed; this is due to the fact that a strong air current develops from the center of the bowl to the periphery. A clay soil when centrifuged 5 minutes loses 3.5 per cent of its moisture due to drying; a sandy soil usually loses less water. In general the loss of moisture is proportional to the maximum molecular moisture holding capacity.

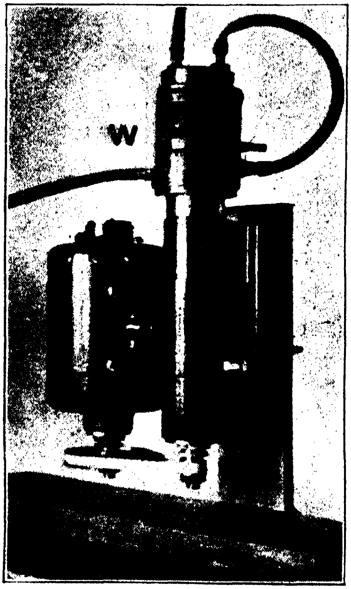

FIGURE 3.—Centrifuge showing the cooling water jacket W. The bowl is located inside of the cooler

A lowering of the temperature in the room where the centrifuging takes place does not remove the evil of evaporation; it simply decreases it. A temperature as low as 0° C. was tried. Neither does the evaporation cease if the centrifuging is done in a chamber saturated with water vapor. Because of the negative character of these experiments the results are not given here.

The loss of moisture due to evaporation may be calculated determining it experimentally for a definite period of time, 2 minutes, centrifuging the

sample 5 and 7 minutes respectively. This method, however, is time consuming and therefore, not practical and for this reason the time of centrifuging was reduced to a minimum.

THE INFLUENCE OF TIME ON THE EFFECT OF CENTRIFUGING

Various soils, clay and sandy, were taken and centrifuged for different periods of time from 1 to 10 minutes. After centrifuging the amount of water in the soil was determined. The results of the observations are given in Table 2.

TABLE 2.—Relationship between time of centrifuging and soil moisture in per cent. Speed of centrifuge sufficient to remove gravitational water, about 70,000 G.

Soil type	Minutes						
	1	2	3	4	5	7.5	10
Clay soil	32.5	32.1	31.6	31.4	30.9	30.0	29.5
Guara-Kingu river, Brazil	34.6	33.5	33.1	32.3	32.4	31.9	31.9
Houston clay, Miss.	25.6	25.1	24.4	24.5	23.4	22.9	22.9
Susquehanna clay loam, Va.		22.9	22.9	23.2	21.0	20.0	19.2
Decatur clay loam, Ga.	18.1	17.8	17.8	17.1	16.5	16.1	15.9
Marshall silt loam, Neb.	13.8	13.9	13.2	13.1	12.7	11.6	11.3
Sassafras silt loam, Md.	7.1	6.2	6.0	6.0	5.9	5.6	5.4

Examining the data in Table 1 one may see that the gravitational water may be removed from the soil within 1 minute if a high speed centrifuge is used. A more prolonged centrifuging is useless; it only lowers the moisture content of the soil by evaporation. Since the soil during the first minute of centrifuging contains some of the gravitational water it may be assumed without great error that during this minute the soil loses by evaporation practically none of its water. Thus the problem of decreasing the evaporation may be solved by cutting down the time of centrifuging to a minimum. In several soils the removal of the gravitational water is not complete within 1 minute (such soils were encountered by the author in a number not greater than 2 per cent out of 300 samples examined) and therefore, the centrifuging was continued in every case for a period of not more than 2 minutes.

If the centrifuge does not develop the power necessary to remove the gravitational water a further centrifuging does not help the removal of the gravitational water as may be seen from the following experiments. The experiments as recorded in Tables 3 and 4 show that whenever the centrifuge does not develop enough power the time factor is not to be considered in removing gravitational water from short columns of soils.

TABLE 3.—Relationship between time of centrifuging and soil moisture in per cent. Speed of centrifuge insufficient to remove gravitational water completely, 400 gravity

Soil type	Minutes				
	5	20	40	60	1[a]
Guara-Kingu river, Brazil	50.8	48.5	48.2	47.9	34.6
Houston clay, Miss.	40.5	39.9	40.9	40.0	25.6
Decatur clay loam, Ga.	39.1	29.7	28.9	29.0	18.1
Sassafras clay loam, Md.	28.4	27.0	26.5	25.6	7.1

[a] 70,000 gravity.

TABLE 4.—Relationship between time of centrifuging and soil moisture in per cent. Speed of centrifuge insufficient to remove gravitational water completely, 1,100 gravity

Soil type	Minutes				
	5	20	40	60	1[a]
Guara-Kingu river, Brazil	41.5	40.6	39.3	39.0	34.6
Houston clay, Miss.	35.1	34.6	33.0	32.9	25.6
Decatur clay loam, Ga.	24.4	23.8	23.5	22.9	18.1
Sassafras silt loam, Md.	21.8	20.7	19.8	19.7	7.1

[a] 70,000 gravity.

THE ACCURACY OF PARALLELED DETERMINATIONS OF THE MAXIMUM MOLECULAR MOISTURE HOLDING CAPACITY BY MEANS OF A HIGH SPEED CENTRIFUGE

Numerous comparative determinations have shown that the difference between two determinations amount to 0.1 to 0.2 per cent. In rare cases the difference goes up to 0.5 per cent and only in special cases the differences reached were 1 per cent. Apparently the most difficult problem in getting an accurate determination of the maximum molecular moisture holding capacity is to get a uniform sample of soil of the same mechanical composition, when the sample equals only 0.5 to 1 g.

THE RELATIONSHIP BETWEEN THE MAXIMUM MOLECULAR MOISTURE HOLDING CAPACITY AND THE SIZE OF SOIL PARTICLES

Since the maximum molecular moisture holding capacity is a function of the inner surface of the soil it must be greater in clay soils and smaller in sandy soils. In order to obtain experimental evidence which characterize the changes of this value in relation to the mechanical composition, the average fractions of the various soil components were taken; these

were obtained from soils by the methods of mechanical analysis used in the Bureau of Soils, U. S. D. A. Table 5 gives the results obtained from 8 parallel determinations for each fraction.

TABLE 5.—Maximum molecular moisture holding capacity of various soil fractions

Fraction	Size of particles	Maximum molecular moisture holding capacity
	mm.	per cent
Coarse sand	1-0.5	1.57
Medium Do	30.5-0.25	1.00
Fine Do	0.25-0.1	2.73
Very fine sand	0.1-0.05	4.75
Silt	0.05-0.005	10.18
Clay	0.005	44.85

Several investigators have shown that by ordinary methods of mechanical analysis the fractions silt and sand contain some clay. Therefore, the figures obtained for the maximum molecular moisture holding capacity for silt (10.18 per cent) and very fine sand (4.75 per cent) should in reality be slightly lower. Off hand one may therefore assume that the maximum molecular moisture holding capacity depends entirely on the clay fraction; in a slightly smaller degree—on the silt fraction and is independent of the sand fraction. Thus, the amount of clay in the soil determines one of the most important hydrological properties of the soil namely its maximum molecular moisture holding capacity.

On the basis of our conception of the physical nature of film water it is natural to expect that a mixture of the various mechanical soil fractions would give the average from the various fractions of the maximum molecular moisture holding capacity. With this in mind clay and medium sand (see Table 5) were mixed in various proportions and the maximum molecular moisture holding capacity determined on these mixtures. This was also calculated theoretically on the basis of the data in Table 5. The results obtained are presented in Table 6 (an average of 3 determinations).

Taking in consideration the fluctuations in determining the maximum molecular moisture holding capacity, even within the same type of soil, one must agree that the determinations of this value in the mixtures of sand and clay as given in the table are almost identical. From the aforesaid it may be concluded that the addition of sand to clay soils decreases the maximum molecular moisture holding capacity of the mixture in proportion to the sand added.

The next experiment illustrates this. The maximum molecular moisture holding capacity was determined: (A) in soils, (B) in the same soils mixed with an equal amount of medium sand, and (C) calculated for

TABLE 6.—Maximum molecular water holding capacity of artificial mixtures of clay and medium sand

Sand	Clay	Obtained experimentally	Calculated
per cent	per cent	per cent	per cent
100	0	1.60	
0	100	44.85	
20	80	36.50	36.20
40	60	26.84	27.55
60	40	18.92	18.90
80	20	9.46	10.25

pure soil on the basis of the determination in the mixtures of soil and sand (Table 7).

TABLE 7.—Determination of maximum molecular water holding capacity of a clay soil and mixtures with sand

Soil	Direct determination with soil	Direct determination in a mixture of 50 per cent soil and 50 per cent sand	Calculated from data obtained on mixtures of soil with sand
	per cent	per cent	per cent
Alabama clay	38.7	20.0	38.4
N30517 from the Marbut collection	35.24	18.62	35.64
Guara-Kingu river, Brazil	33.54	17.50	33.40
N30535 from the Marbut collection	30.23	15.61	29.62

The experiments presented in Tables 6 and 7 show very definitely that the maximum molecular moisture holding capacity of soils is a function of the mechanical composition of soils. On the other hand one may get an idea of the mechanical properties of the soil and a more accurate conception of its inner surface when the maximum molecular moisture holding capacity of the soil is known. From this point of view it is interesting to compare the classification of soils according to their mechanical properties based on actual mechanical analysis with one based on the determination of the maximum molecular moisture holding capacity.

Table 8 gives such a comparison for 19 soils. The data on mechanical analysis of these soils were taken from Davis and Middleton (1). All the mechanical analyses were made by Middleton. The table gives the comparative results as obtained by 3 methods A, C, F. According to Method A which is the standard method of the Bureau of Soils, the soil is shaken for 7 hours in a weak solution of ammonia (1 cc. ammonia per

100 cc. of distilled water). In Method C (Joseph and Martin) the soil is shaken for 1 hour in a 0.2 per cent solution of Na_2CO_3. Method F consists in treating the soil for 1 hour with 0.1 N HCl then washing with water and shaking for 7 hours in 0.05 N NaOH. This last method produces the best dispersion.

The maximum molecular moisture holding capacity was determined on the same samples which Middleton used for his mechanical analysis.[1]

TABLE 8.—Comparison of the classification of soils according to their mechanical properties based on mechanical analysis and one based on their maximum molecular moisture holding capacity

Bureau of Soils No.	Locality and depth of sampling	Maximum molecular water-holding capacity	Classification	Clay	Silt	Sand	Method	Moisture equivalent
415930	Morgan, Ala. 8–36 in.	38.7	Clay	59.5	23.3	16.2	A	40.2
			Do	68.7	16.5	14.8	C	
			Do	68.8	15.6	15.6	F	
450858	Canadian, Okla. 0–6 in.	30.4	Do	40.5	37.8	21.7	A	39.4
			Do	53.1	30.9	16.0	C	
			Do	59.9	24.6	15.5	F	
560809	Yamhill, Oreg. 0–12 in.	28.9	Silt loam	5.6	58.7	35.7	A	39.9
			Clay	39.1	42.5	23.4	C	
			Do	42.4	31.3	26.4	F	
480308[a]	Laramie, Wyo. 8–36 in.	27.9	Do	34.4	12.4	53.2	A	34.3
			Do	38.1	9.2	52.7	C	
			Do	42.6	7.9	49.5	F	
234715	Beaufort, N. C. 7–36 in.	26.2	Do	51.5	33.6	14.9	A	33.8
			Do	58.6	30.3	11.7	C	
			Do	60.4	28.6	11.0	F	
351748[a]	Fraill, N. D. 0–10 in.	26.0	Fine sandy loam	15.0	31.7	53.3	A	37.5
			Clay loam	25.7	34.3	40.0	C	
			Clay	54.4	27.0	28.6	F	
431958	La Salle, La. 7–36 in.	23.9	Do	41.4	42.4	16.2	A	25.1
			Do	41.8	43.0	15.2	C	
			Do	41.0	41.6	17.4	F	
575233[a]	Brawley, Cal. 0–30 in.	23.0	Clay loam	28.6	44.0	27.4	A	27.4
			Clay	39.1	40.9	20.0	C	
			Do	50.6	30.2	19.2	F	
372730[a]	Cheyenne, Neb. 0–10 in.	18.5	Loam	9.2	43.8	47.0	A	27.8
			Do	14.5	36.1	49.4	C	
			Clay loam	24.0	29.7	46.3	F	

[a] Contains calcium carbonate

[1] These samples as well as the results of the mechanical analysis were obtained from Dr. H. E. Middleton to whom I am greatly indebted.

TABLE 8.—(Continued)—Comparison of the classification of soils according to their mechanical properties based on mechanical analysis and one based on their maximum molecular moisture holding capacity

Bureau of Soils No.	Locality and depth of sampling	Maximum molecular water-holding capacity	Classification	Clay	Silt	Sand	Method	Moisture equivalent
415905	Morgan, Ala. 0 8 in.	15.7	Silty clay loam	20.8	67.8	11.4	A	27.5
			Do	23.2	63.1	13.2	C	
			Do	27.0	61.1	12.0	F	
243107	Horry, S. C. 0-30 in.	13.8	Clay loam	20.0	32.7	47.3	A	21.2
			Do	20.4	31.1	48.5	C	
			Do	22.2	28.6	49.2	F	
431911	La Salle, La. 0-10 in.	13.3	Silt loam	17.5	71.8	10.7	A	21.0
			Silt clay loam	21.9	68.4	9.7	C	
			Do	24.5	64.6	10.9	F	
272021	Mahoning, Ohio 6 6 in.	12.9	Do	22.6	50.7	26.7	A	25.7
			Clay loam	22.3	47.0	30.7	C	
			Do	24.1	47.5	28.4	F	
234847	Bertie, N. C. 0-8 in.	11.7	Loam	18.0	49.2	32.8	A	21.9
			Clay loam	20.5	46.9	32.6	C	
			Loam	19.8	43.5	36.7	F	
243150	Horry, S. C. 20-36 in.	10.7	Sandy clay	21.6	7.6	70.8	A	15.6
			Do	22.0	7.1	70.9	C	
			Do	23.2	6.6	70.2	F	
100407	Aroostook, Maine.	6.4	Sandy loam	10.2	28.8	61.0	A	14.4
			Do	9.5	25.5	65.0	C	
			Do	12.6	26.7	60.7	F	
415913	Morgan, Ala. 0 8 in.	4.9	Fine sandy loam	8.4	21.6	70.0	A	9.8
			Do	8.5	22.0	69.5	C	
			Do	12.1	25.1	62.7	F	
242925	Marlboro, S. C. 6 11 in.	4.2	Sandy loam	7.6	15.9	76.5	A	7.7
			Fine sandy loam	8.6	14.0	77.4	C	
			Sandy loam	9.9	14.0	76.1	F	
234815	Bertie, N. C. 0-10 in.	3.9	Fine sandy loam	4.3	19.0	77.7	A	10.4
			Do	3.4	18.6	78.0	C	
			Do	3.7	16.8	79.5	F	

A comparison of soil classifications by Method F and the method according to the characteristics of the maximum molecular moisture holding capacity shows that both methods place all the soils in the same order. It may therefore be assumed that the maximum molecular moisture holding capacity serves as a criterion for the general characteristics of the mechanical composition of the soil. Because of the simplicity and speed of the determination of this value this method may be used in compiling

detailed soil maps showing the mechanical properties of the soil. One may make in a day from 50 to 100 determinations of the maximum molecular moisture holding capacity.

It is expedient to note that by the method of the maximum molecular moisture holding capacity one can not of course determine quantitatively the separate mechanical fractions of the soil. We must remember, however, that the physical properties of the soil are determined by the combination of these fractions. Since the maximum molecular moisture holding capacity is a function of the combined action of all the mechanical elements of the soil on the water it is natural to expect that between the physical properties of the soil and the maximum molecular moisture holding capacity that there exists a simple correlation, more natural and simpler than between the physical properties of the soil and its separate mechanical fractions.

A soil map showing the physical properties of the soil based on the determination of the maximum molecular moisture holding capacity is more closely related to the agronomic characteristics of the soil where one must always consider the combined effects of the individual properties.

The slight variations which appear when a comparison of the two methods are made may be considered as evidence against the physical method, furthermore, the method of mechanical analyses is thus far not perfect as yet; this may be seen from a comparison of the data obtained by Middleton by using the three methods A, C, and F (see Table 8).

It is interesting to pay attention to the moisture equivalent and correlate it with the maximum molecular moisture holding capacity; in all the soils the latter is less than the former. The author is in possession of a great number of observations besides those reported. There is no constant relation between the values of the physical constants mentioned. Very frequently one may notice that the maximum molecular moisture holding capacity is less than the moisture equivalent (8–10 per cent). More striking departures are however observed. The reason for such a phenomenon is that the moisture equivalent is determined with a centrifuge capable of developing a force of 1,000 G; this is not sufficient for the removal of the gravitational water

THE METHOD OF FILM EQUILIBRIUM, THE THIRD METHOD OF DETERMINING THE MAXIMUM MOLECULAR MOISTURE HOLDING CAPACITY

It has been shown previously (Expt. 161) that the movement of the film water takes place very slowly in comparison with the movement of the capillary water. This observation served as a basis for a special method of determining the maximum molecular moisture holding capacity. The soil investigated, A, well moistened, so that it contains a considerable amount of gravitational water, is placed in a layer 1 to 2 mm. thick be-

tween two other layers of drier soil and of a finer texture, namely clay B. The gravitational water of soil A begins to move gradually with the capillaries into the drier and finer soil B; there the water is converted into film water. Such a movement lasts until all the gravitational water from soil A disappears. At this moment only film water remains in soil A. In the finer soil B all the water is at the same time transformed into film water. Under such conditions there is an equilibrium established between the film water of soil A and soil B. This equilibrium is disturbed only very slowly on account of the movement of the film water in soil B in a direction opposite from soil A. However, since such a movement is extremely slow it is possible to detect the film water at the moment when soil A has just been freed from its gravitational water; this may be accomplished by running the experiment 2 days. In the same way the maximum molecular moisture holding capacity of loess (2, p. 73) was determined. At that time the high power centrifuge was not available.

TABLE 9.—The comparison of the maximum molecular moisture holding capacity determined by centrifuge and filter paper methods

No. of sample	Soil	Centrifuge method	Filter paper method
		per cent	per cent
1	Sandy soil	2.66	2.00
2	Susquehanna clay loam, Md.	22.48	20.64
3	Clay soil, Brazil	31.42	32.70
4	Clay soil, Brazil	37.62	34.80
5	Loam soil, Panama	16.24	15.89
6	Clay soil, Brazil	27.24	30.11
7	Sand	0.63	0.82
8	Sand	2.80	2.61
9	Loam, Costa Rica	19.78	21.35
10	Rome, Italy	24.24	23.77
11	Reeds Point, Montana	6.57	9.08
12	Cecil sandy loam, S. Car.	3.89	7.57

Soil B may be substituted with 15 to 20 sheets of filter paper. The time period of the experiment may also be shortened to 5 minutes by decreasing the thickness of the layer of the soil A to 2 mm. With all the modifications the experiment is conducted in the following way: the soil is mixed with water into a thick paste, it is then placed on filter paper in a layer 2 mm. thick. This is conveniently done with the aid of a metal plate 2 mm. thick with a round hole in the center, 3 to 4 cm. in diameter. This hole is filled up with soil, the excess is taken off with a spatula. The soil is then covered with 15 to 20 sheets of filter paper and subjected to a pressure of 500 to 1,000 lb. per square inch. The pressure is applied for 5 minutes. Its purpose is to bring the soil into close contact with the filter paper.

Under such conditions the gravitational water quickly leaves the soil and goes to the filter paper. A determination of the moisture content in the soil is then made and this gives the maximum molecular moisture holding capacity. A series of determinations were made by this method and compared with a centrifuge method. The results obtained are recorded in Table 9.

The experiment shows that very concordant results may be obtained by the two methods. A great many more determinations were made but they are not recorded; it is well to note that in several cases there is quite a difference in the moisture content by the two methods, similar to numbers 11 and 12 in Table 9. Most of these departures are noticed in sandy soils. The author suggests that on the basis of the method of film equilibrium the determination of the maximum molecular moisture holding capacity is correct. There are still a few details which are to be worked out, and this will be the next problem investigated by the author.

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ÜBER KOAGULATIONEN

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EINLEITUNG

Kolloidlehre oder allgemeiner Dispersoidlehre ist die Lehre von den dispersen Systemen. Als bestimmend für viele Eigenschaften der dispersen Systeme muss ihr Dispersitätsgrad oder Zerteilungsgrad angesehen werden. Aenderungen des Dispersitätsgrades sind daher von grundlegender Bedeutung für ein kolloides oder allgemeiner für ein disperses System. Veränderungen des Zerteilungsgrades sind die charakteristischen Reaktionen der Kolloidchemie. Sie können in Vermehrungen oder Verminderungen der Teilchenzahlen, resp. in Verfeinerungen oder in Vergröberungen der Teilchen der dispersen Phase, also des zerteilten Stoffes, bestehen. Vermehrungen oder Verfeinerungen der ursprünglichen Teilchen sind Peptisationen, Verminderungen oder Vergröberungen sind dagegen Koagulationen. Die oft recht augenfälligen Koagulationen sind häufig Gegenstand der experimentellen Untersuchung auch in der Agrikulturchemie und speziell in der Bodenkunde gewesen. Mit solchen Untersuchungen beginnen gewöhnlich die kolloidchemischen Anfänger ihre Betätigung auf diesem Gebiete. Dabei hat die Entwicklung der exakten Grundlagen der Koagulation offenbar nicht Schritt halten können mit der Herausstellung eines geradezu unübersehbaren und häufig ungesichteten empirischen Tatsachenmaterials. Eine Ursache dafür liegt auch darin, dass bei Koagulationen meist die bequem festzustellenden Sekundäreffekte gemessen werden (Aenderung der Viskosität, der Sedimentation, der Trübung, etc.). Nur relativ wenige Untersuchungen liegen über die Aenderungen der primären Teilchenzahlen vor. Sie sind einigermassen mühsam; aber sie können zur Aufstellung exakter Gesetze führen. Liegt nicht gerade in der Verfolgung der Aenderung der wirklichen Teilchenzahlen, die man ultramikroskopisch bestimmen kann, eines der theoretisch anziehendsten Momente der kolloidchemischen Forschung? Wir können doch nur auf ganz wenigen Gebieten chemischer Methodik einem Reaktionsmechanismus so gründlich nachkommen, wie hier, wo uns der ganze Reaktionsablauf buchstäblich "vor Augen liegt", noch dazu in Verdünnungen, wie sie sonst nahezu unzugänglich sind.

Es war ein guter Schritt vorwärts, als M. von Smoluchowski 1916 die Gesetze der raschen und langsamen Koagulation von monodispersen Systemen, d.h. von Systemen mit Teilchen gleicher Grösse, aufstellte. Da die allseitig wirkende Brownsche Bewegung die Ursache des Teilchen-

zusammenstosses ist, nennt man diese Koagulation nach einer neuen Nomenklatur "perikinetische". Die Smoluchowskischen Koagulationsgesetze waren nicht leicht exakt experimentell zu beweisen, weil monodisperse Systeme selten und schwierig herstellbar sind. R. Zsigmondy, A. Westgren, J. Reitstötter, R. Kruyt, A. E. van Arkel, R. Wintgen und A. Ehringhaus, H. Lachs, P. Tuorila und der Verfasser führten Experimental-untersuchungen durch, die die Theorie unter bestimmten Voraussetzungen im weiten Umfange als richtig erwiesen. Nachdem dies einigermassen abgeschlossen war, waren Untersuchungsreihen an den praktisch viel leichter zugänglichen polydispersen Systemen, d.h. an Systemen mit verschieden grossen Teilchen, notwendig. Bereits 1911 hatten der Verfasser und nahezu gleichzeitig A. v. Galecki gezeigt, dass polydisperse Systeme ausgezählt, und dass gewisse Beeinflussungen kleiner Teilchen durch grosse beobachtet werden können. Seit 1916 beschäftigte man sich im Agrikulturchemischen Laboratorium der Eidgen. Technischen Hochschule in Zürich unter Leitung des Verfassers mit quantitativen, ultramikroskopischen Koagulationsstudien an polydispersen Systemen (R. Gallay, G. Koestler, F. Enderlin, E. Scherf). Aber es fehlte noch eine gut brauchbare quantitative Theorie. Da gelang es H. Müller, einer Anregung des Verfassers folgend, im Jahre 1926 die Smoluchowskische Theorie der raschen und langsamen perikinetischen Koagulation monodisperser Systeme auf polydisperse Systeme zu erweitern. Die experimentelle Bestätigung dieser Theorie wurde von P. Tuorila und dem Verfasser im gleichen Jahre geliefert. Darauf arbeitete P. Tuorila in unserm Laboratorium die Gesetze der noch fehlenden raschen und langsamen "orthokinetischen" Koagulation polydisperser Systeme aus, einer wichtigen Koagulation, die durch gegenseitige Bewegung einer bestimmten Teilchengruppe durch eine andere hindurch zustandekommt. Er konnte die von ihm aufgestellten Formeln, die für die Sedimentationsanalyse und für viele andere Absetz-und Aufrahmvorgänge wichtig sind, experimentell gut bestätigen.

Im folgenden wird der Verfasser kurz zusammenfassend über die Arbeiten, die in seinem Laboratorium ausgeführt sind, berichten. Ueber Versuche betr. Koagulation stäbchenförmiger Kolloide und entgegengesetzt geladener Kolloide, die im Gange sind, wird später eine Zusammenfassung gegeben werden.

A. ALLGEMEINE BEMERKUNGEN ÜBER KOAGULATION UND BESTÄNDIGKEIT DISPERSER SYSTEME

Unter *Koagulation* oder *Flockung* versteht man den Vorgang der Teilchenzahlverminderung in einem Dispersoid. Er tritt aus verschiedenen äusseren Ursachen ein, wenn die Stabilitätsbedingungen eines dispersen Systemes so verändert werden, dass das System unbeständiger wird. Disperse Systeme können aus verschiedenen Ursachen beständig sein. Die

Brownsche Bewegung bringt die Teilchen der dispersen Phase von Zeit zu Zeit einander nahe; entweder verhindern nun elektrische Aufladung oder aber Hydratation bezw. Solvatation der Teilchen oder beide nebeneinander die Zusammenballung und damit die Teilchenverminderung. Solange das der Fall ist, bleibt das System beständig.

Ist die elektrische Aufladung die Ursache der Stabilität des Kolloidsystems, so redet man nach H. Freundlich von elektrokratischen Systemen, sind Hydratation oder Solvatation der Grund für die Beständigkeit, dann nennt man nach Wo. Ostwald die Systeme solvatokratisch. In grossen Zügen deckt sich dieses Verhalten mit dem Koagulationsverhalten der suspensoiden oder emulsoiden Zerteilungen. Dass Hydratationen der Jonen auch bei den elektrischen Vorgängen der Entladung der Teilchen eine Rolle spielen, zeigten Wo. Ostwald, G. von Hevesy und der Verfasser (8).

Ein elektrokratisches Sol ist beständig, wenn die Teilchen seiner dispersen Phase über ein bestimmtes kritisches Potential hinaus so hoch aufgeladen sind, dass die Energie der elektrischen Abstossung die Wucht der Brownschen Bewegung überwiegt. Ein solvatokratisches Sol wird dagegen vor allem durch die mit der Konzentration wechselnden Hüllen des Lösungsmittels, die um die Teilchen der dispersen Phase vorhanden sind, vor der Zusammenballung der Einzelpartikel geschützt. Die elektrische Aufladung der Ultramikronen geschieht in den meisten Fällen durch Jonendissoziation oder Jonenadsorption, und zwar so, dass eine gewisse festhaftende Innenschicht von Jonen die elektrische Aufladung des Ultramikrons bestimmt, die durch eine Aussenschicht von entgegengesetzt geladenen Jonen als Hülle oder als Schwarm kompensiert wird (18). Die Solvatation anderseits tritt auf Grund gewisser Quellungs- und Lösungserscheinungen ein, die von der chemischen Natur der dispersen Phase und des Dispersionsmittels, von ihren Nebenvalenzkräften etc. stark abhängig sind. Je "ähnlicher" chemisch Dispersionsmittel und disperse Phase sind, umso höher ist die Solvatation der dispersen Phase.[1]

Es sollen im folgenden vor allem die *Koagulationen elektrokratischer Sole* beschrieben werden, die bisher besonders eingehend durchforscht worden sind.

Das elektrische Potential eines Teilchens der dispersen Phase ist umso grösser, je mehr stabilisierende Jonen adsorbiert oder je mehr Jonen unter Bildung einer aufladenden Jonenschicht vom Ultramikron abdissoziiert sind, und je weiter die Innenbelegung der Haftionen von der Aussenbelegung oder von der umgebenden Hülle der entgegengesetzt geladenen

[1] H. Freundlich und H. Kroch haben in letzter Zeit eine neue Art der Koagulation beschrieben, die weder auf Veränderung der elektrischen Potentiale der Teilchen, noch auf der desolvatation beruht, sondern die ausschliesslich *mechanischer* Natur zu sein scheint; ein elektrolytarmes Sol von Kupferoxyd vermindert seine Teilchenzahl bei unverändertem Potential lediglich durch mechanisches Rühren (1). Vergl. dagegen Wo. Ostwald (9).

kompensierenden Jonen entfernt ist. Die Jonenzahl der Innenschicht wird durch die Stärke der Adsorption oder Dissoziation bestimmt; die Entfernung von Innen- und Aussenbelegung ist dagegen abhängig von der Jonenhydratation. Durch Zusatz von Jonen zum System kann das Potential verändert, häufig erniedrigt werden, indem Innen- und Aussenschicht um das Ultramikron dicht bis nahezu zur völligen Berührung aneinandergedrängt werden.

B. RASCHE UND LANGSAME PERIKINETISCHE KOAGULATION VON MONO- UND POLYDISPERSEN SYSTEMEN

Die *elektrokratische* Koagulation geht nach den Untersuchungen von M. von Smoluchowski und R. Zsigmondy so vor sich, dass oberhalb eines bestimmten elektrischen Potentials keine Zusammenballung der Ultramikronen erfolgt. Die Zusammenstösse der Ultramikronen erfolgen im einfachsten Falle infolge Brownscher Bewegung. Sie sind wirkungslos, solange die Wucht der Brownschen Bewegung schwächer ist als die Energie der elektrischen Abstossung. Wird aber das Potential der Ultramikronen unter ein kritisches Potential erniedrigt, so wird mit abnehmendem Potential ein zunehmender Teil der Zusammenstösse wirksam. Man kommt aus dem Gebiete der Stabilität heraus in das Gebiet der *langsamen* Koagulation. Ist das Potential der Teilchen auf Null erniedrigt, so ist jeder infolge Brownscher Bewegung verursachte Zusammenstoss der Ultramikronen wirksam, und das Gebiet der *raschen* Koagulation ist erreicht. Die Brownsche Bewegung wirkt gleichmässig in allen Richtungen des Raumes. Der Verfasser nannte die durch diese allseitig wirkende Kraft zustandekommende Koagulation "*perikinetisch*". Das System ist *monodispers*, wenn alle Teilchen zu Beginn der Koagulation gleich gross sind. Sind die Teilchen verschieden gross, so bezeichnet man das System als *polydispers*.

I. Die rasche perikinetische Koagulation von monodispersen Systemen

Theoretisch am einfachsten ist das Gebiet der *raschen* perikinetischen Koagulation monodisperser Systeme beim elektrischen Potentiale Null der einzelnen Ultramikronen.

(a) Die mathematische Formulierung der raschen perikinetischen Koagulation nach M. von Smoluchowski.

M. von Smoluchowski (11, 12) hat die Theorie hierfür entwickelt. Grundannahme ist, dass die Teilchen kugelförmig und untereinander gleich gross sind, dass die Systeme also monodispers sind. Die Entladung sei vollständig bis zum Potential Null eingetreten. Die Brownsche Bewegung geht nach der Entladung ungehindert weiter, solange der Abstand der Teilchen grösser als der Radius A einer bestimmten Wir-

kungssphäre ist. Wird der Abstand kleiner, so adhaerieren die Teilchen aneinander. Es bestehen demnach zwischen den Teilchen Anziehungskräfte, über deren Natur Smoluchowski keine bestimmten Vorstellungen entwickelt. Bei den Versuchen stellte sich später heraus, dass der sogenannte Attraktionsradius A annähernd gleich der Summe der Radien der beiden Teilchen ist, die zusammenballten, sodass die Adhaesion erst eintritt, wenn die zwei Teilchen sich ganz oder nahezu ganz berühren. Es wird bei der Entwicklung der Rechnung angenommen, dass die zweifachen, dreifachen, n-fachen Teilchen sich wie die einfachen am Zusammenstosse beteiligen.

Die Endformel, die aus dieser einfachen Vorstellung hervorgeht, ist:

1. $$\nu_0 = \nu_t + \nu \cdot W_1 \cdot \nu_t \cdot t$$

in Worten: Die Summe der Teilchen in der Volumeneinheit zu Anfang der Koagulation ν_0 ist gleich der Teilchenzahl nach der Zeit t, vermehrt um die Zahl der Teilchen, die sich in der Zeit t zusammengeballt haben. Die Zahl der in der Zeit t zusammengeballten Teilchen ergibt sich aus folgender Ueberlegung: Die Wahrscheinlichkeit, dass ein Teilchen ein anderes trifft, sei W_1; dann sind ν_0 Teilchen in t Sekunden in einem Systeme, das ν_t Teilchen enthält mit $\nu_0 \cdot W_1 \cdot \nu_t \cdot t$ anderen Teilchen zusammengetroffen.

Meistens schreibt man die Formel 1 so:

2. $$\nu_t = \frac{\nu_0}{1 + \nu_0 W_1 \cdot t} \quad \text{oder} \quad \nu_t = \frac{\nu_0}{1 + \frac{t}{T_\nu}}$$

T_ν ist die sogenannte halbe Koagulationszeit, d.i. die Zeit, in der die anfängliche Teilchenzahl ν_0 in der Volumeneinheit auf die Hälfte abgenommen hat (es ist dann $t = T_\nu$). Die Wahrscheinlichkeit W_1, dass ein Teilchen ein anderes trifft, ist nach Smoluchowski in einfacher Weise nur von der Diffusionskonstante D_ρ des Teilchens und seinem Attraktionsradius A abhängig. Es ist:

3. $$W_1 = 4\pi A D_\rho.$$

Wenn man diesen Wert von W_1 in die zweite Gleichung $\nu_t = \frac{\nu_0}{1 + \nu_0 W_1 \cdot t}$ einsetzt, erhält man

4. $$\nu_t = \frac{\nu_0}{1 + \nu_0 \cdot t \cdot 4\pi A D_\rho}$$

Schliesslich gibt die bekannte Formel für den Diffusionskoeffizienten D_ρ den Wert

5. $$D_\rho = \frac{k \cdot \Theta}{6\pi N_L \cdot \eta \rho}$$

Dabei bedeuten in C. G. S. Einheiten: $k=83{,}19\cdot 10^6$, $N_L=60{,}6\cdot 10^{22}$, Θ = absolute Temperatur, η = innere Reibung, ρ = Radius der kugelförmigen Teilchen.

Nach Einsetzung des Wertes D_ρ wird die Gleichung 4 zu:

$$6.\qquad \nu_t=\frac{\nu_0}{1+\frac{2}{3}\cdot\frac{k\Theta}{N_L\cdot\eta}\cdot\nu_0 t\frac{A}{\rho}}.$$

Bei 18° gilt: $\Theta=291$, $\eta=0{,}01055$. Also ist bei 18°:

$$7.\qquad \nu_t=\frac{\nu_0}{1+2{,}5244\cdot 10^{-12}\nu_0\cdot t\cdot\frac{A}{\rho}}$$

Aus dieser Formel folgt, dass man $\frac{A}{\rho}$, d.h. das Verhältnis von Attraktionsradius zu Teilchenradius, berechnen kann, wenn man die Anfangsteilchenzahl im Kubikzentimeter ν_0 ferner die Teilchenzahl ν_t zur Zeit t und die Zeit t kennt.

(b) Neue Beobachtungen über die rasche perikinetische Koagulation von Gold- und Kaolinzerteilungen (P. Tuorila)

Wie gut Berechnung und Beobachtung selbst bei starker Variation der Teilchendurchmesser übereinstimmen, zeigen folgende Tabellen (Tabellen 1 und 2):

TABELLE 1.—Rasche perikinetische Koagulation eines monodispersen amikroskopischen Goldsoles (20, S. 5) [1]

Anfangsteilchenzahl: $8{,}438\cdot 10^{11}$ im Kubikzentimeter.
$\Theta=288{,}2$, $\eta=0{,}01$, $\rho=3{,}69\ \mu\mu$. Koagulator: NaCl.

Zeit t in Sekunden	ν_t beob. Teilchenzahl beobachtet nach der Zeit t	ν_t ber. Teilchenzahl, berechnet nach der Zeit t	$\frac{A}{\rho}$ $\frac{\text{Attraktionsradius}}{\text{Teilchenradius}}$	T_ν halbe Koagulationszeit
0	$8438\cdot 10^8$	$8438\cdot 10^8$		
120	$11{,}2\cdot 10^8\pm 0{,}8\cdot 10^8$	$13{,}1\cdot 10^8$	2,82	0,159
195	$7{,}4\cdot 10^8\pm 0{,}6\cdot 10^8$	$8{,}0\cdot 10^8$	2,63	0,170
270	$5{,}3\cdot 10^8\pm 0{,}3\cdot 10^8$	$5{,}8\cdot 10^8$	2,64	0,169
390	$4{,}1\cdot 10^8\pm 0{,}4\cdot 10^8$	$4{,}0\cdot 10^8$	2,39	0,188
450	$3{,}8\cdot 10^8\pm 0{,}3\cdot 10^8$	$3{,}5\cdot 10^8$	2,21	0,202
570	$2{,}6\cdot 10^8\pm 0.2\cdot 10^8$	$2{,}7\cdot 10^8$	2,44	0,175
930	$2{,}0\cdot 10^8\pm 0.1\cdot 10^8$	$1{,}6\cdot 10^8$	2,06	0,217
1260	$1{,}6\cdot 10^8\pm 0.1\cdot 10^8$	$1{,}2\cdot 10^8$	2,18	0,205
			Mittel 2,42	0,186

[1] Zahlreiche Tabellen sind ferner enthalten in der ausführlichen Arbeit von P. Tuorila (14).

TABELLE 2.—Rasche perikinetische Koagulation eines monodispersen Goldsoles mit sehr grossen Teilchen (20, S. 7)

Anfangsteilchenzahl: $3,6 \cdot 10^8$ im Kubikzentimeter. Teilchenradius 97 $\mu\mu$.
$\Theta = 291,7$, $\eta = 0,01$, $\rho = 97\ \mu\mu$. Koagulator: NaCl.

t Zeit in Sekunden	ν_t beob. Teilchenzahl, beobachtet nach der Zeit t	ν_t ber. Teilchenzahl, berechnet nach der Zeit t	$\frac{A}{\rho}$ $\frac{\text{Attraktionsradius}}{\text{Teilchenradius}}$	T_ν halbe Koagulationszeit
0	$3,6 \cdot 10^8 \pm 0,1 \cdot 10^8$	$3,6 \cdot 10^8$		
120	$2,9 \cdot 10^8 \pm 0,1 \cdot 10^8$	$2,9 \cdot 10^8$	2,28	456
240	$2,5 \cdot 10^8 \pm 0,1 \cdot 10^8$	$2,4 \cdot 10^8$	2,01	518
480	$1,9 \cdot 10^8 \pm 0,1 \cdot 10^8$	$1,9 \cdot 10^8$	1,85	507
			Mittel 2,05	507

Die Tabellen 1 und 2 zeigen, dass das Verhältnis $\frac{\text{Attraktionsradius}}{\text{Teilchenradius}} \left(\frac{A}{\rho}\right)$ trotz Aenderung der Radien vom amikroskopischen zum mikroskopischen Gebiet zwischen 2 und 3 liegt, was bedeutet, dass die Teilchen sich nahezu berühren, wenn sie zusammenballen. Die halbe Koagulationszeit T_ν ist konstant. Die berechneten Werte der Teilchenzahlen $\nu_{t\ \text{ber.}}$ und die beobachteten Werte $\nu_{t\ \text{beob.}}$ stimmen innerhalb der Versuchsfehler überein. Dabei wurde ein besonderes neues ultramikroskopisches Zählverfahren ohne Anwendung von Schutzkolloiden von P. Tuorila benutzt (14, S. 265).

Die Teilchenradien wechseln bei diesen hier zitierten Versuchen von 3,69 $\mu\mu$ bis 304 $\mu\mu$. Das Verhältnis von Attraktionsradius zum Teilchenradius lag dabei stets zwischen 2 und 3; die Teilchen adhaerierten auch beim Kaolin erst, wenn sie sich nahezu völlig berührten.

Die Formeln von M. von Smoluchowski lassen sich also für die rasche Koagulation, bei der die Teilchen das Potential Null haben, vollständig bestätigen.

II. Die langsame perikinetische Koagulation von monodispersen Systemen

(a) Die mathematische Formulierung der langsamen perikinetischen Koagulation monodisperser Systeme nach M. von Smoluchowski

Liegt das Potential der Teilchen zwischen dem kritischen Potential und dem Potential Null, so ist die Koagulation eine langsame. Es ist dann nur ein Bruchteil der Zusammenstösse ξ wirksam. Für die rasche perikinetische Koagulation monodisperser Systeme ist $\xi = 1$. Die Formeln sind die gleichen wie vorher, nur die Wahrscheinlichkeit W_2 der Zusammenstösse ist ξ-mal kleiner, nämlich:

8. $$W_2 = 4\pi A D_\rho \xi$$

TABELLE 3.—Rasche perikinetische Koagulation einer monodispersen Kaolinzerteilung. (Kaolin von Zettlitz) (20, S. 9)

Teilchenzahl: $8{,}9 \cdot 10^8$ im cc. Teilchenradius: $0{,}304\ \mu$.
$\Theta = 286{,}7$, $\eta = 0{,}01$, $\rho = 304\ \mu\mu$. Koagulator: NaCl.

t Zeit in Sekunden	ν_t beob. Teilchenzahl, beobachtet nach der Zeit t	ν_t ber. Teilchenzahl, berechnet nach der Zeit t	$\frac{A}{\rho}$ $\frac{\text{Attraktionsradius}}{\text{Teilchenradius}}$	$T\nu$ halbe Koagulationszeit
0	$8{,}9 \cdot 10^8$	$8{,}9 \cdot 10^8$		
90	$6{,}5 \cdot 10^8 \pm 0{,}4 \cdot 10^8$	$6{,}2 \cdot 10^8$	1,75	245
150	$5{,}1 \cdot 10^8 \pm 0{,}3 \cdot 10^8$	$5{,}2 \cdot 10^8$	2,11	203
210	$4{,}4 \cdot 10^8 \pm 0{,}3 \cdot 10^8$	$4{,}5 \cdot 10^8$	2,09	205
270	$3{,}7 \cdot 10^8 \pm 0{,}3 \cdot 10^8$	$3{,}9 \cdot 10^8$	2,28	188
330	$3{,}2 \cdot 10^8 \pm 0{,}2 \cdot 10^8$	$3{,}5 \cdot 10^8$	2,26	189
390	$3{,}1 \cdot 10^8 \pm 0{,}2 \cdot 10^8$	$3{,}1 \cdot 10^8$	2,11	203
510	$2{,}6 \cdot 10^8 \pm 0{,}2 \cdot 10^8$	$2{,}6 \cdot 10^8$	2,03	211
570	$2{,}4 \cdot 10^8 \pm 0{,}2 \cdot 10^8$	$2{,}4 \cdot 10^8$	2,08	206
780	$1{,}8 \cdot 10^8 \pm 0{,}2 \cdot 10^8$	$1{,}9 \cdot 10^8$	2,14	191
1140	$1{,}7 \cdot 10^8 \pm 0{,}1 \cdot 10^8$	$1{,}4 \cdot 10^8$	1,60	267
			Mittel 2,05	211

Daraus folgen die Endformeln für die langsame perikinetische Koagulation:

9. $$\nu_t = \frac{\nu_0}{1 + \nu_0 \xi W_2 t} \quad \text{oder}$$

10. $$\nu_t = \frac{\nu_0}{1 + \xi \frac{t}{T}} \quad \text{resp.}$$

11. $$\nu_t = \frac{\nu_0}{1 + 2{,}5244 \cdot 10^{-12} \nu_0 t \frac{A}{\rho} \xi}.$$

(b) Neue Beobachtungen über die langsame perikinetische Koagulation von Goldzerteilungen durch verschieden stark hydratisierte Kationen (E. Scherf).

Als Beispiele für einen langsamen Koagulationsverlauf sind die folgenden Tabellen der Koagulation von Phosphor-gold, d.h. von kolloidem Gold, reduziert durch Phosphor, gegeben. Es wurde in Tabelle 4 die langsame Koagulation mit Lithiumchlorid, in Tabelle 5 mit Natriumchlorid angeführt.

TABELLE 4.—Langsame perikinetische Koagulation von Phosphorgold mit Lithiumchlorid, (ohne Alkalizusatz) $\nu_0 = 6{,}50 \cdot 10^{10}$ Teilchen im cc. Beobachter: E. Scherf

$\Theta = 287°$, $\eta = 0{,}01$, $\rho = 12{,}55\ \mu\mu$, Koagulator: 0,0287 N LiCl.

$\frac{A}{\rho} = 2{,}5$ (angenommen)

t Zeit in Sekunden	ν_t beob. Teilchenzahl, beob. nach d. Zeit t	ν_t ber. Teilchenzahl, ber. n. d. Zeit t	ξ Bruchteil der wirksamen Zusammenstösse
0	$6{,}50 \cdot 10^{10}$	$6{,}50 \cdot 10^{10}$	
120	$4{,}16 \cdot 10^{10}$	$4{,}36 \cdot 10^{10}$	0,0110
180	$3{,}65 \cdot 10^{10}$	$3{,}66 \cdot 10^{10}$	0,0102
240	$3{,}57 \cdot 10^{10}$	$3{,}28 \cdot 10^{10}$	0,0080
360	$2{,}77 \cdot 10^{10}$	$2{,}63 \cdot 10^{10}$	0,0088
480	$2{,}22 \cdot 10^{10}$	$2{,}19 \cdot 10^{10}$	0,0094
720	$1{,}77 \cdot 10^{10}$	$1{,}65 \cdot 10^{10}$	0,0087
1320	$0{,}94 \cdot 10^{10}$	$1{,}02 \cdot 10^{10}$	0,0105
			Mittel 0,0096

ξ ist annähernd konstant und bedeutet den Bruchteil der wirksamen Zusammenstösse, auf die Einheit 1 bezogen. In Prozenten ausgedrückt waren bei diesem Versuche der Koagulation von Phosphorgold durch ca. 0,03 N Lithiumchlorid nur 0,96 Prozent der Zusammenstösse wirksam.

TABELLE 5.—Langsame perikinetische Koagulation von Phosphorgold mit Natriumchlorid (ohne Alkalizusatz)

$\nu_0 = 6{,}50 \cdot 10^{10}$ Teilchen im cc. Beobachter: E. Scherf
$\Theta = 287°$, $\eta = 0{,}01$, $\rho = 12{,}55\ \mu\mu$, Koagulator: 0,0251 N NaCl.

t Zeit in Sekunden	ν_t beob. Teilchenzahl, beob. nach der Zeit t	ν_t ber. Teilchenzahl, ber. nach der Zeit t	ξ Bruchteil der wirksamen Zusammenstösse
0	$6{,}50 \cdot 10^{10}$	$6{,}50 \cdot 10^{10}$	
120	$3{,}44 \cdot 10^{10}$	$3{,}32 \cdot 10^{10}$	0,0174
240	$2{,}54 \cdot 10^{10}$	$2{,}23 \cdot 10^{10}$	0,0152
300	$2{,}05 \cdot 10^{10}$	$1{,}92 \cdot 10^{10}$	0,0169
360	$1{,}59 \cdot 10^{10}$	$1{,}68 \cdot 10^{10}$	0,0201
480	$1{,}27 \cdot 10^{10}$	$1{,}35 \cdot 10^{10}$	0,0201
600	$1{,}08 \cdot 10^{10}$	$1{,}12 \cdot 10^{10}$	0,0196
720	$0{,}84 \cdot 10^{10}$	$0{,}96 \cdot 10^{10}$	0,0219
			Mittel 0,0187

Der Anteil der wirksamen Zusammenstösse ξ ist hier ebenfalls konstant, er ist im Mittel 0,0187. Es waren also bei der Koagulation von Phosphorgold mit Natriumchlorid 1,87 Prozent der Zusammenstösse wirksam. Die Konzentration des Lithiumchlorids war 0,0287 N, bei Natriumchlorid nur 0,0251 N. Trotzdem waren beim Koagulieren mit Natriumchlorid in dieser Verdünnung doppelt so viel Zusammenstösse der Ultramikronen wirksam als beim Lithiumchlorid, was mit der grösseren Hydratation des Lithiumions zusammenhängt. Man sieht, wie hier zahlenmässig die Hydratationseffekte die Wirkung der Koagulation beeinflussen. (Interessanterweise ist auch beim Basenaustausch Natriumchlorid doppelt so wirksam wie Lithiumchlorid (Umtauschkonstante Lithium 15,21, Natrium 29,46 (6, S. 451).

Wie sich der Bruchteil der wirksamen Zusammenstösse mit der Konzentration ändert, ist noch wenig bekannt. E. Schalek und A. Szegvary (13) gaben eine einfache Formel; während H. H. Paine und U. R. Evans (10) eine verwickeltere Beziehung der kinetischen Theorie experimentell bestätigten.

Jedenfalls lässt sich die Richtigkeit der Anschauungen von Smoluchowski über die Koagulation monodisperser Systeme sehr gut experimentell beweisen. Es ergibt sich: Die *rasche* perikinetische Koagulation findet so statt, dass auch die entladenen Teilchen den Gesetzen der Brownschen Bewegung unterliegen und dass sie zusammenballen, sobald sie durch diese Bewegung zur gegenseitigen Berührung kommen. Bei der *langsamen* Koagulation monodisperser Systeme ist nur ein Bruchteil der Zusammenstösse wirksam.

III. Die rasche perikinetische Koagulation von polydispersen Systemen

Die Gesetze von Smoluchowski gelten nur für die perikinetische Koagulation von gleich grossen teilchen, die Kugelgestalt haben, also für monodisperse Systeme. Solche Systeme sind in der Praxis relativ selten. Meistens handelt es sich praktisch um Systeme, die eine ganze Anzahl von verschiedenen Teilchengrössen haben. Man nennt solche Systeme, wie erwähnt, "polydisperse" Systeme, und zwar bidispers, wenn zwei monodisperse Teilchengruppen nebeneinander vorhanden sind, tridispers bei drei Gruppen etc. Schon 1911 haben der Verfasser (16) und nahezu gleichzeitig A. v. Galecki (3) ausgesprochen, dass grosse Teilchen in einem solchen Systeme kleine beeinflussen müssen oder dass kleinere Teilchen die Tendenz haben, sich an grössere, nicht an die der gleichen Grössenordnung, anzulagern. Grosse Ultramikronen wirken für kleinere als Koagulationskerne.

(a) Die mathematische Formulierung der raschen perikinetischen Koagulation polydisperser Systeme nach H. Müller.

Bereits M. von Smoluchowski (12, Anm. S. 145) hat sich mit diesem Effekt theoretisch beschäftigt. Die Wahrscheinlichkeit des Zusammenstosses W_1 von zwei gleichgrossen Teilchen ist nach ihm (vergl. Gleichung 3)

$$W_1 = 4\pi A_1 \cdot D_\rho$$

A_1 = Attraktionsradius des Teilchens mit dem Radius ρ, meist $A_1 = 2p$.
D_ρ = Diffusionskoeffizient des Teilchens mit dem Radius ρ.

Smoluchowski schreibt dazu: "Streng genommen wäre allerdings die gegenseitige Anlagerungsgeschwindigkeit ungleicher Teilchen grösser als jene gleichgrosser, was vielleicht in Betracht kommen könnte, falls man es von vornherein mit einem Gemische von Teilchen sehr bedeutender Grössenunterschiede zu tun hat." Für die Wahrscheinlichkeit W_2 des Zusammenstosses von zwei verschiedengrossen Teilchen, die die Radien R und r und die zugehörigen Diffusionskoeffizienten D_R und D_r haben, gilt

12. $$W_2 = 2\pi A_2(D_R + D_r).$$

Hierbei ist A_2 der wirksame Attraktionsradius, der gleich der Radiensumme der beiden Teilchen $R+r$ ist. Immer ist:

$$W_2 > W_1, \text{ wobei } W_1 = 4\pi A_1 D_\rho, \text{ (vergl. Formel 3).}$$

Die Wahrscheinlichkeit W_2, dass ein grosses und ein kleines Teilchen zusammenstossen, ist grösser als die Wahrscheinlichkeit W_1, dass zwei gleichgrosse Teilchen sich treffen.

H. Müller (7) hat nun die Verhältnisse für die rasche Koagulation theoretisch erörtert, wie sie in einem bidispersen Systeme vorhanden sind, das N grosse Teilchen vom Radius R und n kleine Teilchen vom Radius r im cc. enthält. Es wird in seiner Ableitung für alle Zusammenstösse von kleinen Teilchen und von Komplexen der kleinen Teilchen die Wahrscheinlichkeit $W_1 = 4\pi A_1 D_r$ benutzt, wie es Smoluchowski für die monodispersen Systeme tat. Die gleiche Wahrscheinlichkeit $W_1' = 4\pi A_1' D_R$, die dieselbe Grösse wie W_1 hat, wird für die Zusammenstösse von grossen Teilchen untereinander und von Komplexen, die mindestens ein grosses Teilchen enthalten, gebraucht. Aber für alle Zusammenstösse von kleinen Teilchen und ihren Komplexen, die nur aus kleinen Teilchen bestehen, mit grossen Teilchen und mit Komplexen, die mindestens *ein* grosses Teilchen enthalten, wird die grössere Wahrscheinlichkeit W_2 nach der Formel 12 benutzt:

$$W_2 = 2\pi A_2 \ (D_R + D_r).$$

H. Müller setzt $W_2 = \gamma W_1$, wobei $\gamma = \dfrac{(R+r)^2}{4R \cdot r}$ ist.

Der Attraktionsradius A_2 ist gleich der Radiensumme $r+R$. Die Formel, die man schliesslich erhält, gilt für die Summe aller grossen und kleinen

Teilchen und für ihre Komplexe t Sekunden nach Beginn der raschen perikinetischen Koagulation. Sie lautet:

$$13. \qquad N_t + n_t = \frac{N_0}{1+\frac{t}{T_{N_0}}}\left[1+\frac{\lambda}{(\lambda V_n+1)\left(1+\frac{t}{T_{N_0}}\right)^{\lambda}-1}\right]$$

t ist die Zeit in Sekunden, gerechnet nach Beginn der raschen perikinetischen Koagulation.

n_t ist die Zahl aller kleinen Teilchen und der Komplexe nur aus kleinen Teilchen im cc. zur Zeit t Sekunden nach Beginn der raschen perikinetischen Koagulation.

N_t ist die Zahl aller grossen Teilchen und der Komplexe mit mindestens einem grossen Teilchen, t Sekunden nach Beginn der Koagulation.

N_0 ist die Zahl der grossen Teilchen im cc. am Anfange der Koagulation.

T_{N_0} ist die halbe Koagulationszeit für die grossen Teilchen.

T_{N_0} ist $\frac{1}{W_1 N_0}$ (vergl. Gleichung 2), wobei $W_1 = 4\pi A_1 D_R$ und $A_1 = 2$ R ist.

Für λ gilt:

$$\lambda = \frac{Vr^2+1}{2V_r}, \text{ wenn } V_r = \frac{R}{r} \text{ gesetzt wird.}$$

R ist der Radius der grossen Teilchen und r der der kleinen.

V_n ist $\frac{N_0}{n_0}$, wenn N_0 die Zahl der grossen Teilchen in 1cc. am Anfange der Koagulation und n_0 die der kleinen Teilchen zur selben Zeit ist.

(b) Experimentelle Bestätigung der Formel von H. Müller für die rasche perikinetische Koagulation polydisperser Systeme (G. Wiegner und P. Tuorila).

Die Formel 13 von H. Müller sagt aus, dass die Koagulation in einem Systeme mit verschieden grossen Teilchen stets rascher verläuft als die Koagulation in einem Systeme mit derselben Anzahl gleichgrosser Teilchen. Hat man sehr viele grosse Teilchen neben wenigen kleinen, so ist die Abweichung vom Verlaufe der monodispersen Koagulation, wie sie M. v. Smoluchowski berechnet, nicht gross; die ganze perikinetische polydisperse Koagulation ähnelt dann der monodispersen der grossen Teilchen. Wenn man umgekehrt im Anfang sehr viele kleine Teilchen neben wenigen grossen im System hat, so beobachtet man hauptsächlich den Verlauf der monodispersen Koagulation von kleinen Teilchen.

Am deutlichsten wird der Effekt der polydispersen, perikinetischen Koagulation, wenn man eine mittelgrosse Zahl von möglichst grossen Ultramikronen (etwa 10^9 im cc.) neben einer sehr grossen Zahl von Amikronen anwendet. Dann kommt die polydisperse Koagulation nahe heran an die monodisperse Koagulation der mittelgrossen Zahl von

grossen Teilchen, weil das Zusatzglied $\dfrac{\lambda}{\left(\lambda V_n+1\right)\left(1+\dfrac{t}{T_{N_0}}\right)^{\lambda}-1}$ in der Formel 13 sehr klein wird. Die Smoluchowskische Formel, angewendet auf die hohe Zahl aller Teilchen (der grossen und der kleinen) würde viel höhere Werte ergeben, die Abweichung des polydispersen Koagulationsverlaufes vom monodispersen ist also dann relativ stark. Der Unterschied zwischen mono- und polydisperser perikinetischer Koagulation lässt sich erst sicher nachweisen, wenn das Verhältnis der Radien der beiden Teilchengruppen etwa 10 ist, also $\frac{R}{r}$ ca. 10.

Folgende Zahlen von P. Tuorila (20, S. 16) (Tabelle 6) zeigen das:

TABELLE 6.—Rasche perikinetische Koagulation eines polydispersen Goldsoles

Radienverhältnis 9,54 : 1.

$\Theta = 290$, $\eta = 0{,}01$, $R = 51{,}22\ \mu\mu$, $r = 5{,}37\ \mu\mu$, $N_0 = 20{,}2 \cdot 10^8$, $n_0 = 5799 \cdot 10^8$, $V_r = 9{,}54$, $V_n = 0{,}00348$. Koagulator: NaCl.

t Zeit in Sekunden	(N_t+n_t), beob. Teilchenzahl im cc. beobachtet nach der Zeit t	(N_t+n_t), berechnet nach H. Müller als polydisperse Koagulation $\frac{A}{R}=2{,}36$	(n_t+N_t), berechnet nach Smoluchowski als monodisperse Koagulation $\frac{A}{\rho}=2{,}36$
0	$5819{,}2 \cdot 10^8$	$5819{,}2 \cdot 10^8$	$5819{,}2 \cdot 10^8$
120	$8{,}3 \cdot 10^8 \pm 0{,}5 \cdot 10^8$	$8{,}5 \cdot 10^8$	$13{,}3 \cdot 10^8$
240	$4{,}9 \cdot 10^8 \pm 0{,}3 \cdot 10^8$	$5{,}0 \cdot 10^8$	$6{,}6 \cdot 10^8$
480	$2{,}5 \cdot 10^8 \pm 0{,}2 \cdot 10^8$	$2{,}8 \cdot 10^8$	$3{,}3 \cdot 10^8$

Man sieht, dass die rasche perikinetische Koagulation des polydispersen Systemes [(N_t+n_t) beob. in der zweiten Vertikalspalte] rascher vor sich geht, als man nach Smoluchowski (4. Vertikalspalte) für monodisperse Systeme berechnet. Die Berechnung nach H. Müller (3. Vertikalspalte) deckt sich ausgezeichnet mit der Beobachtung.

Noch deutlicher werden die Unterschiede zwischen der Koagulation mono- und polydisperser Systeme, wenn man die Radien noch stärker variiert. Beim folgenden Versuche mit polydispersen Gold verhielten sich die Radien der grossen zu denen der kleinen Teilchen wie 33,32 : 1.

Aus dieser Tabelle 7 geht noch deutlicher hervor, als aus Tabelle 6, dass die rasche perikinetische Koagulation von bidispersen Systemen mit zwei stark verschiedenen Radiengrössen bedeutend schneller ist, als die der monodispersen Zerteilungen.

Es lässt sich also experimentell zeigen, dass die Formeln von H. Müller für die rasche perikinetische Koagulation polydisperser (spez. bidisperser)

Systeme richtig sind. Polydisperse Systeme koagulieren bei vollständiger Entladung ihrer Teilchen, also bei rascher Koagulation, schneller als monodisperse. Allerdings macht sich der Unterschied erst bei Radienverschiedenheiten von 1 : 10 deutlich geltend.

TABELLE 7.—Rasche perikinetische Koagulation eines polydispersen Goldsoles
Radienverhältnis 33,32 : 1
$\Theta = 292{,}2$, $\eta = 0{,}01$, $R = 97{,}0\ \mu\mu$, $r = 2{,}91\ \mu\mu$, $N_0 = 3{,}6 \cdot 10^8$, $n_0 = 29282 \cdot 10^8$, $V_r = 33{,}32$, $V_n = 0{,}000123$. Koagulator: NaCl.

t Zeit in Sekunden	(N_t+n_t) beob. Teilchenzahl in 1 cc. beobachtet nach der Zeit t	(N_t+n_t) berechnet nach H. Müller als polydisperse Koagulation $\frac{A}{R} = 2{,}05$	(N_t+n_t) berechnet nach Smoluchowski als monodisperse Koagulation $\frac{A}{\rho} = 2{,}05$
0	$29282 \cdot 10^8$	$29282 \cdot 10^8$	$29282 \cdot 10^8$
120	$4{,}5 \cdot 10^8 \pm 0{,}1$	$4{,}4 \cdot 10^8$	$15{,}2 \cdot 10^8$
240	$3{,}3 \cdot 10^8 \pm 0{,}2$	$2{,}5 \cdot 10^8$	$7{,}6 \cdot 10^8$
480	$2{,}1 \cdot 10^8 \pm 0{,}1$	$1{,}9 \cdot 10^8$	$3{,}8 \cdot 10^8$

Viele Kolloidzerteilungen, deren Radien unterhalb der Grenzen 1 : 10 variieren, lassen sich annähernd und noch genau genug nach Smoluchowski berechnen; sie verhalten sich als wären sie monodispers. Die Brownsche Bewegung ballt erfahrungsgemäss gleich grosse Teilchen ganz ähnlich zusammen, wie verschieden grosse, wenn die Verschiedenheit unter 1 : 10 bleibt.

Was die Gesetze der *langsamen* perikinetischen Koagulation polydisperser Systeme anbetrifft, so wäre analog den Ansätzen von M. v. Smoluchowski in den Formeln von H. Müller die Zahl der wirksamen Zusammenstösse zu berücksichtigen (Einsetzung des ξ-Faktors). Voraussetzung dafür wäre, dass das Potential der grossen und kleinen Teilchen dasselbe wäre. Ob das bis zu amikroskopischen Teilchen der Fall ist, wissen wir nicht. Deshalb sei auf die Diskussion der Formeln der langsamen perikinetischen Koagulation polydisperser Systeme verzichtet.

C. DIE RASCHE UND LANGSAME ORTHOKINETISCHE KOAGULATION NACH P. TUORILA

Viel wichtiger als der Einfluss der Brownschen Bewegung auf das Koagulationsverhalten ist ein anderer Faktor, der stark bei der Koagulation verschiedengrosser Teilchen hervortritt, wenn sie vollständig entladen sind und wenn sie dadurch rasch koagulieren. Grosse Teilchen bewegen sich nämlich rascher unter dem Einflusse einer *einseitig* gerichteten Kraft (wie Schwerkraft oder Zentrifugalkraft) als kleinere, und sie

haben dadurch eine grössere Wahrscheinlichkeit, mit anderen kleineren Teilchen in dieser einen Richtung zusammenzustossen, als in allen andern Richtungen des Raumes. War die Brownsche Bewegung die Ursache für die Zusammenstösse der Teilchen und wirkte sie in allen Richtungen des Raumes gleichmässig, so nannte der Verfasser die dadurch verursachte Koagulation nach vollständiger oder unvollständiger Entladung rasche oder langsame *perikinetische* Koagulation. Bewegt sich aber ein grosses Teilchen einseitig im System, sei es durch Fallen oder durch Zentrifugieren, so ist die Wahrscheinlichkeit des Zusammenstosses in dieser einen geraden Richtung grösser als in allen andern Richtungen und wir wollen die durch diese Bewegung in *einer* Richtung verursachten Zusammenstösse als *orthokinetische* Zusammenstösse und die dadurch hervorgerufene Koagulation *orthokinetische Koagulation* nennen.

I. Die mathematische Formulierung der raschen und langsamen orthokinetischen Koagulation nach P. Tuorila

Mein Mitarbeiter Dr. Pauli Tuorila (15) hat die in dieses Gebiet gehörigen Arbeiten ausgeführt, nachdem uns vorher die experimentelle Bestätigung der Gesetze der polydispersen Koagulation nach H. Müller gelungen war (14). Die Betrachtungen, die er anstellt, sind folgende [1]: Es sollen sich unter dem Einflusse der Schwerkraft grössere Teilchen neben kleineren bewegen. Wir nehmen an, dass in 1 cc. des Systems weniger als 10^7 bis 10^8 Gesamtteilchen im Durchschnitt vorhanden sind, da dann zwischen ihnen in 30 Minuten, während der wir beobachten, keine nachweisbare perikinetische Koagulation eintritt. Diese Annahme vereinfacht unsere Darstellungen. Sie ist nicht unbedingt notwendig. P. Tuorila hat auf den Seiten 48 bis 53 seiner Arbeit gezeigt, wie man auch das Zusammenwirken der ortho- und perikinetischen Koagulation berechnen kann. Für unsere vereinfachten Ueberlegungen sei vorausgesetzt, dass die Teilchenzahl unter 10^7 bis 10^8 im cc. bleibe, wodurch keine Komplikation infolge von perikinetischer Koagulation eintreten kann.

Wir machen nun folgende weitere *Annahmen:*

Grössere Teilchen attrahieren kleinere aus einem Attraktionsvolumen, das den Querschnitt $\pi(A^2-R^2)$ hat; A ist dabei der Attraktionsradius, der zweckmässig gleich der Summe der Radien der grossen und kleinen Teilchen $(R+r)$ gesetzt wird.

Die Länge des Stromes, der beladen mit kleineren Teilchen in der Zeiteinheit am grossen Teilchen vorbeifliesst, sei L. Dann ist das Strömungsvolumen aus dem in der Zeiteinheit die kleinen Teilchen durch ein grosses entnommen werden können: $\pi(A^2-R^2)L$.

(a) Betrachtungen über das sog. "Hautraumvolumen."

[1] Für ein tieferes Eindringen in die Gesetzmässigkeiten muss auf die Originalarbeiten P. Tuorilas verwiesen werden.

Tuorila hat dieses Strömungsvolumen in der Zeiteinheit als "Hautraumvolumen" der grossen Teilchen bezeichnet, das er für ein einziges grosses Teilchen mit b, für eine Summe von N grossen Teilchen mit $N\,b=B$ benennt. Danach ist das Hautraumvolumen für ein grosses Teilchen:

14. $b=\pi(A^2-R^2)L$ und für N grosse Teilchen:

15. $$N\,b=B=\pi(A^2-R^2)L\cdot N.$$

Um ein Mass für die Länge des Strömungsvolumens L zu erhalten, sei angenommen, dass L proportional der Geschwindigkeitsdifferenz der beiden Teilchen sei.[1] Diese Geschwindigkeitsdifferenz wird zweckmässig nach der Formel von G. Stokes berechnet. Wenn v_R die Geschwindigkeit der grossen Teilchen und v_r die der kleinen ist, dann gilt nach G. Stokes:

16. $$v_R-v_r=\frac{2}{9}\,\frac{g(D-d)(R^2-r^2)}{\eta}.$$

Dabei haben die Buchstaben die bekannte Bedeutung: g ist die Schwerkraft, D die Dichte der fallenden Teilchen, d die Dichte des Dispersionsmittels und η ist die innere Reibung. Zweckmässig wird in C. G. S. Einheiten gemessen.

Es soll also nach unserer Annahme die Länge des Strömungsvolumens L proportional der Geschwindigkeitsdifferenz der grossen und kleinen Teilchen, also proportional (v_R-v_r) oder auch proportional $\frac{2}{9}\,\frac{g(D-d)(R^2-r^2)}{\eta}$ sein. Es ist danach, wenn k_1 der Proportionalitätsfaktor ist:

17. $$L=k_1\left[\frac{2}{9}\,\frac{g(D-d)(R^2-r^2)}{\eta}\right]$$

und das Hautraumvolumen eines grossen Teilchen in der Zeiteinheit ist:

18. $$b=\pi(A^2-R^2)k_1\frac{2}{9}\,\frac{g(D-d)(R^2-r^2)}{\eta}.$$

Bei konstanter Temperatur können wir $\pi k_1\frac{2}{9}\,\frac{g(D-d)}{\eta}$ zu einer neuen Konstante k_2 zusammenfassen, sodass wir erhalten:

19. $$b=k_2(A^2-R^2)(R^2-r^2).$$

Setzen wir nun in Uebereinstimmung mit den Annahmen von M. v. Smoluchowski und mit den Versuchen von R. Zsigmondy und vielen anderen für den Attraktionsradius $A=R+r$, so wird:

$$b=k_2(2R^3r+R^2r^2-2Rr^3-r^4).$$

[1] Sicher wird die Länge L des Strömungsvolumens proportional einer Funktion dieser Geschwindigkeitsdifferenz sein. Die erste Annäherung ist die obige Annahme, dass die Länge direkt proportional der Geschwindigkeitsdifferenz ist.

Führt man zur Vereinfachung $S = \frac{r}{R}$ ein, so kann die letzte Gleichung für das Hautraumvolumen eines Teilchens auch geschrieben werden:

20. $$b = k_2 R^4 (2S + S^2 - 2S^3 - S^4).$$

Wichtiger als das Hautraumvolumen b eines einzelnen Teilchens ist das gesamte Hautraumvolumen B von N grossen Teilchen. Es ist:

21. $$B = k_2 N R^4 (2S + S^2 - 2S^3 - S^4).$$

Sind durchschnittlich M Gramm grosse Teilchen in 1 cc. des Systems vorhanden, so ist das Gewicht eines grossen Teilchens gleich $\frac{M}{N}$. Dieses Gewicht eines grossen Teilchens kann auch als ein Volumen, multipliziert mit dem spezifischen Gewichte s desselben Teilchens, berechnet werden, also als $\frac{4}{3}\pi R^3 s$. Mithin ist:

$$\frac{M}{N} = \frac{4}{3}\pi R^3 s \text{ oder } \frac{3M}{4\pi R^3 s} = N.$$

Setzt man diesen Wert für N in die Formel 20: $B = k_2 N R^4 (2S + S^2 - 2S^3 - S^4)$ ein, so bekommt man die neue Formel:

$$B = \frac{k_2 \cdot 3M}{4\pi R^3 s} R^4 (2S + S^2 - 2S^3 - S^4).$$

22. $$B = \frac{k_2 \cdot 3M}{4\pi s} R (2S + S^2 - 2S^3 - S^4).$$

Wir wollen $\frac{3k_2}{4\pi s}$ mit K_3 bezeichnen und $S = \frac{r}{R}$ aus der Klammer herausheben. Dann erhalten wir:

23. $$B = k_3 M r (2 + S - 2S^2 - S^3).$$

Der gesamte Hautraum B einer Menge M von grossen Teilchen ist proportional dieser Menge M der grossen Teilchen und ist abhängig von der Funktion $r(2 + \frac{r}{R} - \frac{r^2}{R^2} - \frac{r^3}{R^3})$. Wird $r = 0$, so gibt es keinen Hautraum, denn das System ist dann monodispers. Dasselbe gilt, wenn $\frac{r}{R} = 1$ ist. Auch dann gibt es keinen Hautraum, weil das System ebenfalls monodispers ist. Zwischen $\frac{r}{R} = 0$ und $\frac{r}{R} = 1$ können die Werte variieren.

P. Tuorila hat nun den Wert für das Hautraumvolumen B in der Zeiteinheit unter verschiedenen Voraussetzungen diskutiert. Diese Betrachtungen findet man auf den Seiten 30–37 seiner Arbeit, auf denen

gezeigt wird, dass das Hautraumvolumen B einer Menge M, bei einem Verhältnis der Radien $\frac{r}{R}$ bis 0,4, nur um wenige Prozente (etwa 5%) variiert. Das Hautraumvolumen in der Zeiteinheit kann innerhalb der Fehlergrenzen für das Radienverhältnis $\frac{r}{R}$ bis zu 0,4 als konstant angenommen werden.

(b) Experimentelle Voraussetzungen für die mathematische Formulierung der orthokinetischen Koagulation.

Bleibt die durchschnittliche Gesamtzahl der Teilchen in 1 cc. des Systemes *unter* 10^7 bis 10^8, so koagulieren sie *nicht* perikinetisch miteinander, wie folgender Versuch zeigt (Tabelle 8) (15, S. 17):

TABELLE 8.—Rasche perikinetische Koagulation monodisperser Goldsole mit verschiedenen Anfangsteilchenzahlen (ν_0)

Koagulator: 0,2 N $CaCl_2$, $\Theta = 287{,}2$, $\eta = 0{,}0117$, $\rho = 34{,}5$ $\mu\mu$

Zeit in Sekunden	Anfangsteilchenzahlen im cc. (ν_0)					
	10^8		$0{,}5 \cdot 10^8$		$0{,}1 \cdot 10^8$	
	Teilchenzahlen im cc. (ν_t)					
	beob.	ber.	beob.	ber.	beob.	ber.
0	$1 \cdot 10^8$	$1 \cdot 10^8$	$0{,}5 \cdot 10^8$	$0{,}5 \cdot 10^8$	$0{,}1 \cdot 10^8$	$0{,}1 \cdot 10^8$
300	$0{,}8 \cdot 10^8$	$0{,}9 \cdot 10^8$	$0{,}5 \cdot 10^8$	$0{,}5 \cdot 10^8$	$0{,}1 \cdot 10^8$	$0{,}1 \cdot 10^8$
600	$0{,}8 \cdot 10^8$	$0{,}8 \cdot 10^8$	$0{,}5 \cdot 10^8$	$0{,}4 \cdot 10^8$	$0{,}1 \cdot 10^8$	$0{,}1 \cdot 10^8$
900	$0{,}7 \cdot 10^8$	$0{,}7 \cdot 10^8$	$0{,}4 \cdot 10^8$	$0{,}4 \cdot 10^8$	$0{,}1 \cdot 10^8$	$0{,}1 \cdot 10^8$
1800	$0{,}5 \cdot 10^8$	$0{,}5 \cdot 10^8$	$0{,}3 \cdot 10^8$	$0{,}4 \cdot 10^8$	$0{,}1 \cdot 10^8$	$0{,}09 \cdot 10^8$
3600	$0{,}4 \cdot 10^8$	$0{,}4 \cdot 10^8$	$0{,}3 \cdot 10^8$	$0{,}3 \cdot 10^8$	$0{,}1 \cdot 10^8$	$0{,}09 \cdot 10^8$
5400	$0{,}4 \cdot 10^8$	$0{,}3 \cdot 10^8$	$0{,}3 \cdot 10^8$	$0{,}2 \cdot 10^8$	$0{,}1 \cdot 10^8$	$0{,}08 \cdot 10^8$
7200	$0{,}3 \cdot 10^8$	$0{,}2 \cdot 10^8$	$0{,}3 \cdot 10^8$	$0{,}2 \cdot 10^8$	$0{,}1 \cdot 10^8$	$0{,}08 \cdot 10^8$

Die Fehler der Beobachtung betragen dabei 10 bis 15 Prozent. Das Verhältnis von Attraktionsradius zu Teilchenradius $\frac{A}{\rho}$ war 2,1 : 1. Entsprechende Zahlen, die zeigen, dass die sog. rasche perikinetische Koagulation bei 10^8 bis 10^7 Teilchen sehr langsam wird, wurden von P. Tuorila für Paraffinsole, Quarzsuspensionen, Graphitsuspensionen und Tonsuspensionen gefunden.

Nur für eine Tonsuspension sei noch eine Tabelle herausgegriffen (Tabelle 9) (15, S. 22).

Das Verhältnis Attraktionsradius : Teilchenradius war 2,5 : 1. Man sieht aus der Tabelle 8 und auch aus 9, dass innerhalb der später verwendeten Versuchszeit von 30 Minuten oder 1800 Sekunden keine ausser-

TABELLE 9.—Rasche perikinetische Koagulation feiner monodisperser Tonsuspensionen mit verschiedenen Anfangsteilchenzahlen (ν_0)

Koagulator: 0,25 N $CaCl_2$, $\Theta = 287{,}2$, $\eta = 0{,}0117$

Zeit in Sekunden	Anfangsteilchenzahl in cc. ($\nu_0 = 1 \cdot 10^{-7}$) Teilchenzahl in cc. (ν_t) beob.	berechn.
0	$1 \cdot 10^{-7}$	$1 \cdot 10^{-7}$
300	$1 \cdot 10^{-7}$	$0{,}98 \cdot 10^{-7}$
600	$1 \cdot 10^{-7}$	$0{,}97 \cdot 10^{-7}$
3600	$1 \cdot 10^{-7}$	$0{,}83 \cdot 10^{-7}$
7200	$0{,}8 \cdot 10^{-7}$	$0{,}72 \cdot 10^{-7}$

halb der Versuchsfehler von 10 bis 15 Prozent liegende Verminderung der Teilchenzahl experimentell nachweisbar ist.

Unsere Versuchsbedingung, dass unter 10^{-7} Teilchen in 1 cc. des Systemes vorhanden sind, gewährleistet also, dass innerhalb der Versuchszeit keine perikinetische Koagulation auftreten kann. Wenn man das Radienverhältnis $\frac{r}{R}$ kleiner als 0,4 wählt, bleibt auch das Hautraumvolumen in der Zeiteinheit bis auf 5 Prozent konstant. Dann sollte die Wirkung der orthokinetischen Koagulation eindeutig bei den Versuchen herauskommen, wenn überdies noch bestimmte Bedingungen über die Menge der kleinen Teilchen im Verhältnis zur Menge der grossen Teilchen eingehalten werden. Die Menge der kleinen Teilchen zur Menge der grossen Teilchen sollte kleiner als 0,4 sein (vergl. S. 225).

(c) Die mathematische Formulierung der Teilchenabnahme durch rasche orthokinetische Koagulation.

P. Tuorila stellte folgende *Betrachtung über die Abnahme* der Zahl der kleinen Teilchen, die durch grosse mitgerissen werden, an:

Der Hautraum, aus dem die kleinen Teilchen durch eine Menge von M grossen Teilchen in der Zeiteinheit vollständig entnommen werden, sei B, wobei $B = M \cdot b$ ist; also der Gesamthautraum B ist gleich der Summe aller Einzelhauträume b von M grossen Teilchen in 1 cc.

In 1 cc. Suspension seien durchschnittlich n kleine Teilchen enthalten. Dann werden aus B cc. Hautraum in einer Zeiteinheit $B \cdot n$ kleine Teilchen entnommen und in dt Zeiteinheiten $B \cdot n \cdot dt$. Die Abnahme der durchschnittlichen Teilchenzahl ist anderseits dn, und es muss demnach sein:

24. $$-dn = B \cdot n \cdot dt \quad \text{oder}$$

$$-\frac{dn}{n} = B \cdot dt \quad \text{oder}$$

25. $$-\frac{dn}{n} = M \cdot b \cdot dt.$$

Dabei bedeutet n die durchschnittliche Anzahl der kleinen Teilchen in 1 cc., die beim Durchfallen einer Menge M von grossen Teilchen in 1 cc. des Systems die einzeln den Hautraum b cc. haben, noch vorhanden ist. Es ist in dieser Formel keine Annahme über die Grösse der grossen Teilchen gemacht. Es muss nur $\frac{r}{R} < 0{,}4$ sein. Die Zeit t ist die Zeit, während der die grossen Teilchen auf die kleinen wirken können.

Wenn obige Gleichung zwischen den Zeiten $t=0$ und $t=t$ integriert wird, bekommt man:

26. $$-\log n = \int_0^t B \cdot dt = \int_0^t M \cdot b \cdot dt.$$

Der Wert $\int_0^t M \cdot b \cdot dt$ ist gleich $M \cdot b \int_0^t dt = M \cdot b \cdot t$, falls $M \cdot b$, also der Hautraum pro Zeiteinheit, auch während der Koagulation konstant bleibt. Das ist annähernd der Fall, wenn, wie erwähnt, das Radienverhältnis $\frac{r}{R}$ kleiner als 0,4 ist. Ferner sollte das Verhältnis der durchschnittlichen Menge der kleinen Teilchen m im cc. zur Menge der grossen Teilchen M im cc., also $\frac{m}{M}$, kleiner als 0,4 sein. P. Tuorila diskutiert dies exakt auf den Seiten 29–48 seiner Arbeit. Wenn $\frac{m}{M} < 0{,}4$ und $\frac{r}{R} < 0{,}4$ sind, kann $M \cdot b$ während der Koagulation als konstant angesehen werden, solange die Teilchen kugelförmig sind. Die grossen Teilchen können ihrerseits ganz verschiedene Grösse der Radien haben, ebenso können die Radien der kleinen Teilchen um das 8-fache untereinander variieren, ohne dass die Formel für die Mittelwerte der Gruppen ihre Gültigkeit verliert, wie rechnerisch von Tuorila gezeigt wird. Es sei hier nur das Endresultat der umfangreichen Rechnungen gebracht, für die Einzelheiten muss die Originalarbeit herangezogen werden.

Die Gleichung 26 kann integriert werden, unter der Bedingung, dass $N_0 + n_0 < 1 \cdot 10^7$, $\frac{r}{R} < 0{,}4$ und $\frac{m}{M} < 0{,}4$ sind. Man bekommt dann:

27. $$-\log n = Mbt + \text{Const.}$$

Wenn die durchschnittliche Anzahl der kleinen Teilchen im cc. zu Beginn der Versuche n_0 ist, gilt für $t=0$ auch $n = n_0$, und die Integrationskonstante wird $\log n_0$. Dann bekommt man die Gleichung:

$$-\log n - \log n_0 = M \cdot b \cdot t \qquad \text{oder}$$

$$\log \frac{n}{n_0} = -M \cdot b \cdot t \qquad \text{oder}$$

$$e^{-Mbt} = \frac{n}{n_0}$$

28. $$n_0 e^{-Mbt} = n.$$

In dieser Gleichung [1] bedeuten:

n_0 = durchschnittliche Zahl der kleinen Teilchen in 1 cc. des Systems zu Beginn des Versuches.

n = durchschnittliche Zahl der kleinen Teilchen in 1 cc. des Systems nach t Sekunden.

M = durchschnittliche Menge der grossen Teilchen in 1 cc. des Systems.

b = Hautraum in cc. pro Sekunde für die Menge von 1 Gramm der grossen Teilchen in 1 cc. des Systems.

Setzt man $Mb = B$, so kann man Gleichung 28 schreiben:

29. $$n_0 e^{-Bt} = n.$$

Diese Endformel gibt also den Zusammenhang zwischen der durchschnittlichen Teilchenzahl n in 1 cc. der Suspension nach der Zeit t Sekunden, wenn im Anfange n_0 Teilchen in 1 cc. vorhandenwaren.

Im Systeme folgen nun alle Schichten von oben nach unten aufeinander. Jeder Schichthöhe entspricht eine bestimmte Fallzeit $t_0, t_1, t_2, \ldots$, in der grosse Teilchen diese Schicht passiert und orthokinetisch koagulierend gewirkt haben. Es soll jetzt die durchschnittliche Zahl n_H der kleinen Teilchen berechnet werden, die in 1 cc. des Systems zwischen zwei Schichten H_{t_1} und H_{t_2}, entsprechend den Fallzeiten t_1 und t_2 der kleinsten von den grossen Teilchen, zurückgeblieben ist. Diese Zahl ist der Mittelwert aus allen Einzelwerten, die n annehmen kann für alle aufeinander folgenden Schichten, die innerhalb der Zeiten t_1 und t_2 von den kleinsten der grossen Teilchen durchlaufen werden und die die Einzelwerte $n_0 e^{-Bt}$ haben. Also es ist:

$$n_H = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} n_0 e^{-Bt} dt = \frac{1}{t_2 - t_1} \left[\frac{n_0 e^{-Bt_1}}{B} - \frac{n_0 e^{-Bt_2}}{B} \right]$$

30. $$n_H = \frac{n_0}{B(t_2 - t_1)} (e^{-Bt_1} - e^{-Bt_2}).$$

[1] Was die Masseinheiten betrifft, so kann man Teilchenzahlen und Teilchenmengen im Kubikzentimeter oder im Liter der Suspension angeben. Der Hautraum wird dann in Kubikzentimetern oder in Litern pro Sekunde erhalten. Sowohl das Verhältnis $\frac{N_0}{n}$, als das Produkt $M \cdot b$ sind vom Volumen des Systems unabhängig.

n_H ist die gesuchte durchschnittliche Zahl der kleinen Teilchen, die in 1 cc. der Suspension zurückbleiben, wenn die Menge von M grossen Teilchen in 1 cc. des Systems $t_2 - t_1$ Sekunden gewirkt hat. Hierbei ist wieder der Hautraum B der Summe der einzelnen Hauträume einer Menge von M grossen Teilchen gleich, also $B = M \cdot b$.

Häufig soll die durchschnittliche Zahl der kleinen Teilchen berechnet werden, die in 1 cc. der Suspension zwischen der Höhe H_0, entsprechend der Zeit 0, und der Höhe H_t, entsprechend einer Zeit t, vorhanden ist, also zwischen der Oberflächenschicht und einer bestimmten, darunterliegenden Schicht H_t, die von den kleinsten der grossen Teilchen nach t Sekunden durchlaufen ist. Dann wird in der Gleichung 30: $t_1 = 0$ und $e^{-Bt_1} = 1$, und wir erhalten:

31. $$n_H = \frac{n_0}{Bt_2}(1 - e^{-Bt_2}) \qquad \text{oder}$$

$$n_H = \frac{n_0}{Mbt_2}(1 - e^{-Mbt_2}) \qquad \text{oder}$$

32. $$\frac{n_H}{n_0} = \frac{1}{Mbt_2}(1 - e^{-Mbt_2}).$$

Sind n_0 die durchschnittliche Anfangszahl der kleinen Teilchen in 1 cc. des Systems und n_H die mittlere Zahl der kleinen Teilchen in 1 cc. des Systems zwischen der Oberfläche und einer Schichttiefe H cm. bekannt, so ermöglicht die Gleichung 32 die Kubikzentimeter des gesamten Hautraumes Mb einer Menge M von grossen Teilchen in 1 cc. des Systems zu berechnen. Statt der durchschnittlichen *Zahlen* der kleinen Teilchen n_0 resp. n_H in 1 cc. Suspension können in die Formel 32 auch die durchschnittlichen *Mengen* der kleinen Teilchen pro cc. m_0 zu Anfang und m_H nach der Zeit t_2 eingesetzt werden. Die Gleichung 32 lautet dann:

33. $$\frac{m_H}{m_0} = \frac{1}{Mbt_2}(1 - e^{-Mbt_2}).$$

M ist die durchschnittliche Menge der grossen Teilchen in 1 cc. der Suspension. 1 Gramm der grossen Teilchen hat den Hautraum b cc. Zur Vereinfachung der Berechnung wird die folgende *Hilfstabelle* benutzt (Tabelle 10).

Da die Masseinheiten für die Teilchenzahlen resp. Teilchenmengen in den linken Seiten der Schlussformeln durch Division herausfallen, können Zahlen und Mengen der zurückbleibenden kleinen Teilchen im Kubikzentimeter oder im Liter der Suspension gegeben werden. Das Produkt Hautraumvolumen multipliziert mit der Zeit bedeutet entsprechend Kubikzentimetersekunden oder Litersekunden.

Nach Tabelle 10, die auf Grund der Gleichungen 32 oder 33 berechnet ist, lässt sich die Richtigkeit des Gesetzes prüfen, wenn das Verhältnis von

TABELLE 10.—Zusammenhang zwischen dem Verhältnis

$$\frac{\textit{zurückgebliebene Mittelzahl der kleinen Teilchen } n_H}{\textit{mittlere Anfangszahl der kleinen Teilchen } n_0}$$

resp.

$$\frac{\textit{zurückgebliebene durchschnittl. Menge der kleinen Teilchen } m_H}{\textit{mittlere Anfangsmenge der kleinen Teilchen } m_0}$$

und dem Produkt Gesamthautraum der grossen Teilchen Mb, multipliziert mit der Zeit t_2

$\frac{n_H}{n_0}$ beob. oder $\frac{m_H}{m_0}$ beob. Mengenverhältnis	Mbt_2 Hautraum multipliziert mit Zeit	$\frac{n_H}{n_0}$ beob. oder $\frac{m_H}{m_0}$ beob. Mengenverhältnis	Mbt_2 Hautraum multipliziert mit Zeit
1,0000	0	0,3790	2,4
0,9065	0,2	0,3560	2,6
0,8233	0,4	0,3354	2,8
0,7520	0,6	0,3167	3,0
0,6884	0,8	0,2998	3,2
0,6321	1,0	0,2843	3,4
0,5823	1,2	0,2702	3,6
0,5380	1,4	0,2573	3,8
0,4982	1,6	0,2454	4,0
0,4637	1,8	0,2197	4,5
0,4324	2,0	0,1987	5,0
0,4042	2,2	0,1810	5,5
		0,1663	6,0

Teilchenzahlen oder Teilchenmengen $\frac{n_H}{n_0}$ resp. $\frac{m_H}{m_0}$ nach der Zeit t_2 beobachtet ist. Der Wert Mb muss für ein bestimmtes M konstant und bei wechselndem M proportional der Grösse von M sein.

(d) Die mathematische Formulierung der Teilchenabnahme durch langsame orthokinetische Koagulation.

Die orthokinetische Koagulation kann, was besonders betont sei, nur eintreten, wenn eine Entladung der Teilchen unter ein kritisches Potential stattgefunden hat, also nach Zusatz von Elektrolyten. Auch hier kann man, wie bei der perikinetischen Koagulation ein Gebiet der langsamen orthokinetischen Koagulation von einem der raschen unterscheiden.

Die Ansätze für die langsame orthokinetische Koagulation sind ganz ähnlich wie die für die rasche vorausgesetzt, dass die Teilchenentladung für grosse und kleine Teilchen im gleichen Masse erfolgt. Man hat nur den gesamten Hautraum (Mb) der orthokinetisch wirkenden grösseren Teilchen mit einem Faktor ξ zu versehen, der die Zahl der orthokinetisch wirksamen Zusammenstösse angibt. Dieser Faktor ξ hat den Wert 1 für

die rasche orthokinetische Koagulation, bei der alle Zusammenstösse wirksam sind.

II. Experimentelle Bestätigung der Formeln für die rasche orthokinetische Koagulation (P. Tuorila)

(a) Bestimmung der zurückbleibenden Teilchenmengen bei der raschen orthokinetischen Koagulation von Quarzsuspensionen.

P. Tuorila prüfte experimentell die quantitativen Zusammenhänge. Es wurde ein besonders gereinigtes, gewaschenes und geglühtes Quarzsandpräparat von C. A. F. Kahlbaum verwendet. Im Atterbergschen Schlämmzylinder waren daraus zwei verschiedene Fraktionen hergestellt. Die Koagulationen wurden als schnelle Koagulationen mit einer im Gemisch halbnormalen Salzsäure als Koagulator durchgeführt. Der Koagulator wurde sehr rasch zu Beginn des Versuches zugefügt. Grosse und kleine Teilchen waren in zwei Gruppen gemischt. Bei allen Versuchen, die man in Messzylindern ausführte, wurden die von den grossen fallenden Teilchen nicht mitgerissenen kleineren Teilchen nach einer gewissen Zeit, in der die kleinsten der grossen Teilchen bis zu einer bestimmten Höhe abgesunken waren, mit einer Pipette abgehebert. Die Pipettenmündung, die bis zur gewünschten Tiefe eingetaucht wurde, war aufwärts gebogen. Sie war so eng, dass nur die Flüssigkeit oberhalb der Pipettenmündung eingesogen wurde, was gut gelang, wie experimentell gezeigt werden konnte. Die abgesogene Suspension wurde gründlich durchgemischt, und es wurde dann in einem Teile der Mittelwert der Teilchenmenge im Liter bestimmt.

Die beiden Teilchengruppen, die im Atterbergschen Zylinder hergestellt waren, waren nicht völlig monodispers, d.h. sie hatten nicht durchwegs gleiche Teilchendurchmesser. Das ist zur Prüfung der Richtigkeit der Formel von Tuorila auch nicht nötig. Die Durchmesser der kleinen Teilchen schwankten von 0,5 μ bis 2 μ, die der grossen von 7 μ bis 16 μ.

Bei allen hieher gehörigen Versuchen wurden $m_0 = 1{,}295$ g. kleine Quarzteilchen durchschnittlich in 1 Liter Suspension, entsprechend $n_0 = 2{,}29 \cdot 10^8$ Teilchen im cc. durchschnittlich, verwendet. Die Menge M der grossen Teilchen war verschieden; sie betrug bei den einzelnen Versuchen 7,35, 14,70, 29,40, oder 58,80 g. im Liter, entsprechend $0{,}12 \cdot 10^7$, $0{,}24 \cdot 10^7$, $0{,}48 \cdot 10^7$ und $0{,}96 \cdot 10^7$ Teilchen durchschnittlich im cc. Die perikinetische Koagulation ist innerhalb der Beobachtungszeit nicht wirksam, was rechnerisch bewiesen werden kann und was experimentell nochmals festgestellt wurde. Die Teilchen koagulieren nur orthokinetisch.

Die folgenden vier Tabellen enthalten einige Ergebnisse der Versuche. In den Tabellen bedeuten: Θ absolute Temperatur, η innere Reibung, m_0 die durchschnittliche Menge der kleinen Teilchen im Anfange in Grammen pro Liter, m_H die durchschnittliche Menge der kleinen Teilchen in

Grammen pro Liter, die nach t_2 Sekunden in der Suspension zurückgeblieben sind, M die durchschnittliche Menge der grossen Teilchen in Grammen pro Liter, t_2 die Zeit in Sekunden von Anfang bis zur Probenahme, Ht_1 und Ht_2 die Fallhöhen in cm., die die kleinsten von den grossen Teilchen zu den Zeiten t_1 und t_2 Sekunden durchlaufen haben. Mb ist der Gesamthautraum von M grossen Teilchen in 1 Liter Suspension, gemessen in Litern. Die berechneten Fehler sind mittlere Fehler.

Die Berechnung geschah so, dass zuerst aus $\frac{m_H \text{ beob.}}{m_0}$ der Wert von Mbt_2 aus der Tabelle 10 entnommen wurde. Daraus wurde der Wert von Mb berechnet. Mit dem konstanten Mittelwerte von Mb wurden dann nach der Formel 33.

$\frac{m_H \text{ ber.}}{m_0} = \frac{1}{Mbt_2}(1 - e^{-Mbt_2})$ die Werte von m_H ber. ermittelt.

TABELLE 11.—Rasche orthokinetische Koagulation einer Suspension von 1,295 g. kleinen Quarzteilchen (Teilchenradius 0,5 – 2,0 μ) und 7,35 g. grossen Quarzteilchen (Teilchenradius 7 – 16 μ) in 1 Liter. Koagulator HCl (im Gemisch 0,5 N)

$\Theta = 286°$, $\eta = 0{,}012$, $m_0 = 1{,}295$ g., $M = 7{,}35$ g., $\frac{m_0}{M} = 0{,}176$, $Ht_0 = 18$ cm.

Zeit in Sekunden t_2	Schichthöhendifferenz od. Fallweg der grossen Teilchen $(H_{t_1} - H_{t_2})$ cm.	Beobachtete Grammenge de kleinen Teilchen, die zwischen H_{t_1} und H_{t_2} im Liter zurückblieben m_H beob.	Berechnete Grammenge d. kleinen Teilchen, die zwisch. H_{t_1} und H_{t_2} im Lit. zurückblieben m_H ber.	Gesamthautraum d. grossen Teilchen in 1 Lit. Suspension in Litern multipliziert mit t_2 Sekunden Mbt_2	Gesamthautraum d. grossen Teilchen in 1 Lit. Suspension in Litern pro Sekunde Mb
0		1,295 ±0,015	1,295		
330	18,0 – 13,5	1,04 ±0,03	1,01	0,45	0,00136
660	18,0 – 9,0	0,82 ±0,01	0,81	1,01	0,00153
990	18,0 – 4,5	0,64 ±0,02	0,66	1,62	0,00164
330	18,0 – 13,5	1,04 ±0,03	1,01	0,45	0,00136
330	13,5 – 9,0	0,60 ±0,03	0,60	0,53	0,00160
330	9,0 – 4,5	0,28 ±0,04	0,34	0,62	0,00188
					Mittel 0,00156

Die Tabellen 11 bis 14 zeigen, dass die Formel 33: $\frac{m_H}{m_0} = \frac{1}{Mbt_2}(1 - e^{-Mbt_2})$ die Abnahme der Menge der kleinen Teilchen durch orthokinetische Koagulation innerhalb der Versuchsfehler sehr gut berechnen lässt. Der Wert von Mb (der Hautraum in Litern pro Sekunde der grossen Teilchen aufgeschlämmt in 1 Liter Suspension) ist innerhalb der Fehlergrenzen befriedigend konstant, wie die letzten Vertikalspalten der Tabellen ausweisen. Diese Werte Mb müssen natürlich im Verhältnis der Mengen

TABELLE 12.—Rasche orthokinetische Koagulation einer Suspension von 1,295 g. kleinen Quarzteilchen (Teilchenradius 0,5 – 2,0 μ) und 14,7 g. grossen Quarzteilchen (Teilchenradius 7 – 16 μ) in 1 Liter. Koagulator HCl (im Gemisch 0,5 N)

$$\Theta = 286{,}2,\ \eta = 0{,}012,\ m_0 = 1{,}295\ \text{g.},\ M = 14{,}7\ \text{g.},\ \frac{m_0}{M} = 0{,}088,\ H_{t_0} = 18\ \text{cm.}$$

Zeit in Sekunden t_2	Schichthöhen-differenz od. Fallweg der grossen Teilchen $(H_{t_1} - H_{t_2})$ cm.	Beobachtete Grammenge der kleinen Teilchen die zwischen H_{t_1} und H_{t_2} im Liter zurückblieben m_H beob.	Berechnete Grammenge d. kleinen Teilchen, d. zwischen H_{t_1} und H_{t_2} im Liter zurückblieben m_H ber.	Gesamthautraum d. grossen Teilchen in 1 Lit. Suspension in Litern multipliziert mit t_2 Sekunden Mbt_2	Gesamthautraum d. grossen Teilchen in 1 Lit. Suspension in Litern pro Sekunde Mb
0		1,295 ±0,015	1,295		
330	18,0 – 13,5	0,76 ±0,02	0,77	1,17	0,00355
660	18,0 – 9,0	0,50 ±0,01	0,51	2,33	0,00353
990	18,0 – 4,5	0,37 ±0,01	0,37	3,39	0,00342
330	18,0 – 13,5	0,76 ±0,01	0,77	1,17	0,00355
330	13,5 – 9,0	0,24 ±0,015	0,24	1,17	0,00355
330	9,0 – 4,5	0,10 ±0,015	0,06	1,05	0,00318
					Im Mittel 0,00346

der grossen Teilchen, die angewandt wurden, zueinander stehen. Dies ist der Fall, wie die nächste Uebersicht beweist:

TABELLE 13.—Rasche orthokinetische Koagulation einer Suspension von 1,295 g. kleinen Quarzteilchen (Teilchenradius 0,5 – 2,0 μ) und 29,4 g. grossen Quarzteilchen (Teilchenradius 7 – 16 μ) in 1 Liter. Koagulator HCl (im Gemisch 0,5 N)

$$\Theta = 286{,}2,\ \eta = 0{,}012,\ m_0 = 1{,}295\ \text{g.},\ M = 29{,}4\ \text{g.},\ \frac{m_0}{M} = 0{,}044,\ H_{t_0} = 18\ \text{cm.}$$

Zeit in Sekunden t_2	Schichthöhen-differenz od. Fallweg der grossen Teilchen $(H_{t_1} - H_{t_2})$ cm.	Beobachtete Grammenge der kleinen Teilchen, die zwischen H_{t_1} und H_{t_2} im Liter zurückblieben m_H beob.	Berechnete Grammenge d. kleinen Teilchen, d. zwischen H_{t_1} und H_{t_2} im Liter zurückblieben m_H ber.	Gesamthautraum d. grossen Teilchen in 1 Lit. Suspension in Litern multipliziert mit t_2 Sekunden Mbt_2	Gesamthautraum d. grossen Teilchen in 1 Lit. Suspension in Litern pro Sekunde Mb
0		1,295 ±0,015	1,295		
132	18,0 – 16,2	0,90 ±0,02	0,895	0,77	0,00583
264	18,0 – 14,4	0,63 ±0,02	0,65	1,66	0,00629
330	18,0 – 13,5	0,58 ±0,01	0,57	1,90	0,00576
396	18,0 – 12,6	0,48 ±0,01	0,50	2,42	0,00612
726	18,0 – 8,1	0,30 ±0,01	0,29	4,21	0,00580
					Im Mittel 0,00596

Tatsächlich stehen die aus den Experimenten berechneten Werte für die Gesamthauträume im selben Verhältnis zueinander, wie die angewandten Mengen der grossen Teilchen, wie es die Ableitung der Formeln

TABELLE 14.—Rasche orthokinetische Koagulation einer Suspension von 1,295 g. kleinen Quarzteilchen (Teilchenradius 0,5 – 2,0 μ) und 58,8 g. grossen Quarzteilchen (Teilchenradius 7 – 16 μ) in 1 Liter. Koagulator HCl (im Gemisch 0,5 N)

$$\Theta = 286{,}2°,\ \eta = 0{,}012,\ m_0 = 1{,}295 \text{ g.},\ M = 58{,}8 \text{ g.},\ \frac{m_0}{M} = 0{,}022,\ H_{t_0} = 18 \text{ cm.}$$

Zeit in Sekunden	Schichthöhendifferenz od. Fallweg der grossen Teilchen	Beobachtete Grammenge der kleinen Teilchen, die zwischen H_{t_1} und H_{t_2} im Liter zurückblieben	Berechnete Grammenge d. kleinen Teilchen, d. zwischen H_{t_1} und H_{t_2} im Liter zurückblieben	Gesamthautraum d. grossen Teilchen in 1 Lit. Suspension in Litern multipliziert mit t_2 Sekunden	Gesamthautraum d. grossen Teilchen in 1 Lit. Suspension in Litern pro Sekunde
t_2	$(H_{t_1} - H_{t_2})$ cm.	m_H beob.	m_H ber.	Mbt_2	Mb
0		1,295 ± 0,015	1,295		
330	18,0 – 13,5	0,29 ± 0,02	0,315	4,43	0,0134
660	18,0 – 9,0	0,16 ± 0,02	0,16	8,10	0,0123
990	18,0 – 4,5	0,12 ± 0,01	0,11	10,80	0,0109
					Mittel 0,0122

erfordert. P. Tuorila hat diese Tatsache noch durch eine Reihe von weiteren Experimenten bestätigt (vergl. S. 70 seiner Arbeit), sodass diese Tatsache sichergestellt ist.

Die orthokinetische Wirkung hängt von den *Radien der grossen Teilchen* ab, was praktisch wichtig ist.

TABELLE 15.—Proportionalität zwischen der Menge der grossen Teilchen und ihren experimentell ermittelten Gesamthautraum

Tabelle	Grammenge der orthokinetisch wirkenden grossen Teilchen in 1 Liter Suspension	Verhältniszahlen der angewandten Mengen	Liter Gesamthautraum pro Zeiteinheit der grossen Teilchen in 1 Lit. Suspension, beob. nach den Tab. 11–14	Verhältniszahlen der Gesamthauträume beob.	berech.
14	58,80	8	0,01220	8 statt	8
13	29,40	4	0,00596	3,9 Do	4
12	14,70	2	0,00346	2,3 Do	2
11	7,35	1	0,00156	1,0 Do	1

Wenn die grossen Teilchen eine gewisse Radiengrösse überschreiten, dann reissen sie schliesslich keine kleineren Teilchen mehr mit, wie das

P. Tuorila zeigte. Es wurde ermittelt, dass z.B. in Quarzsuspensionen Quarzteilchen mit Radien grösser als 20 μ nicht mehr perikinetisch auf kleinere Teilchen wirken. Offenbar tritt ein Abreissen der kleineren Teile bei sehr rascher Bewegung der grösseren ein, sodass kein orthokinetischer Effekt merkbar wird. Koaguliert ein System von verschiedensten Teilchengrössen, so ist die orthokinetische Wirkung bei Teilchen über 20 μ Radius überhaupt nicht nachweisbar; sie ist nur gering bei Radien von 10–20 μ, dagegen gross bei Radien von 6–10 μ. Für Radien von 5–6 μ erreicht die orthokinetische Wirkung für Quarzsuspensionen ihr Maximum. Die Radien unter 4μ verschwinden in einer aus allen Korngrössen gemischten Quarzsuspension durch orthokinetische Koagulation vollständig.

Bei Ton- und Bodensuspensionen, die aus Teilchen von allen Radiengrössen gemischt sind, entstehen durch orthokinetische Koagulation Aggregate von 10–20 μ Radius. Grössere Aggregate entstehen nicht. Tonteilchen mit Radien, die kleiner als 10 μ sind, verschwinden praktisch vollständig durch orthokinetische Koagulation.

(b) Verhalten der Suspensionen nach Aufladung der Teilchen über das kritische Potential.

Sind die Teilchen *über* das kritische Potential aufgeladen, was durch Entfernung der Elektrolyte oder durch stabilisierend wirkende Jonenzusätze erreicht werden kann, so ist kein Zusammenstoss zwischen den Teilchen mehr wirksam, weil die elektrischen Abstossungskräfte die Attraktionskräfte überwiegen. Dann kann man Suspensionen von sehr hohem Gehalt an Teilchen herstellen, in denen die Teilchen ganz unabhängig voneinander sedimentieren. P. Tuorila prüfte das in besonderen Experimenten. Er stellte verschieden konzentrierte Suspensionen von polydispersem Quarz (Quarz zur Analyse C. A. F. Kahlbaum) her, die weit über das kritische Potential (70 Millivolt) geladen waren. Die durchschnittlichen Anfangsmengen im Liter waren 21,5; 43,2; 64,0; 85,6; 107,6 und 151,0 Gramm. Diese Mengen verhielten sich wie 1,00 : 2,00: 2,97 : 3,97 : 4,99 : 7,00. Während 60 Minuten wurde die Sedimentation im Wiegnerschen Schlämmapparat aus 70 cm. Höhe beobachtet. Die nächste Tabelle zeigt, dass die Sedimentation, wenn die Teilchen über das kritische Potential aufgeladen sind, völlig unabhängig von der suspendierten Menge ist. Das gegenseitige Verhältnis der noch schwebenden Teilchenmengen (V. Z.) bleibt während der ganzen Sedimentationszeit dasselbe, wie bei Beginn des Versuches.

Die Tabelle 16 beweist, dass während des ganzen Sedimentationsvorganges aus der gleichen Höhe von 70 cm. innerhalb einer Stunde das gegenseitige Verhältnis der Teilchenmengen dasselbe bleibt wie im Anfange.

TABELLE 16.—Unabhängigkeit des Sedimentationsverlaufes von verschiedenen Quarzmengen in Wasser, die über das kritische Potential aufgeladen sind

(V-Z bedeutet Verhältniszahl der jeweils in den einzelnen Suspensionen noch schwebenden Teilchenmengen, verglichen mit den Teilchenmengen der konzentriertesten Suspension, deren Menge gleich 7 gesetzt ist.)

Zeit vom Beginn der Sedimentation an in Minuten	Menge der Quarzteilchen in der Suspension in Grammen je Liter (durchschnittlich) während des Absetzens aus einer 70 cm. dicken Schicht V-Z= Verhältniszahl											
	Menge	V-Z	Menge	V-Z	Menge	V-Z	Menge	V-Z	Menge	V-Z	Menge	V-Z
0	21,5	0,997	43,2	2,0	64,0	2,97	85,6	3,985	107,6	4,97	151,0	7,0
1	16,4	1,03	33,3	2,11	49,5	3,12	67,0	4,22	78,4	4,94	111,0	7,0
3	13,8	1,10	24,7	1,98	39,0	3,12	51,4	4,12	60,9	4,88	87,4	7,0
5	11,7	1,05	21,8	1,96	33,2	2,99	43,5	3,92	53,1	4,78	77,8	7,0
10	9,4	1,07	17,3	1,97	26,9	3,07	35,3	4,03	43,0	4,91	61,4	7,0
20	7,5	1,10	14,1	2,07	21,6	3,22	28,2	4,14	34,5	5,06	47,2	7,0
30	6,6	1,10	11,8	1,97	19,0	3,15	24,5	4,08	30,2	5,03	42,0	7,0
40	5,9	1,05	10,4	1,86	17,2	3,07	22,2	3,97	27,1	4,84	39,2	7,0
50	5,2	1,00	9,5	1,83	16,0	3,08	21,0	4,04	25,5	4,91	36,4	7,0
60	4,7	0,96	9,3	1,90	14,6	2,99	19,6	4,01	24,3	4,98	34,2	7,0
Mittel von V-Z:		1,05		1,97		3,08		4,05		4,93		7,00

Zur leichteren Übersicht sind die hauptsächlichsten Daten der Tabelle 16 in der folgenden Tabelle 17 nochmals zusammengestellt:

TABELLE 17.—Verhältnis der Teilchenmengen einer über das kritische Potential aufgeladenen Suspension zu Anfang und während des Koagulations-verlaufes

'eilchenmenge in Grammen pro Liter zu Beginn	Verhältnis der Mengen zu Beginn (die konzentrierteste Suspension mit 151 g. Quarz pro Lit. ist 7 gesetzt.)	Verhältnis der durchschnittl. Mengen während der Sedimentation, aus den Beobachtungen zu verschiedenen Zeiten berechnet.
21,5	1,00	1,05
43,2	2,00	1,97
64,0	2,97	3,08
85,6	3,97	4,05
107,6	4,99	4,93
151,0	7,00	7,00

Die Sedimentation von suspendierten Teilchen, die über das kritische Potential aufgeladen sind, ist demnach praktisch unabhängig von der suspendierten Menge.

D. ANWENDUNG DER GESETZE DER ORTHOKINETISCHEN KOAGULATION AUF DIE SCHLÄMMANALYSE (SEDIMENTANALYSE NACH WIEGNER-GESSNER) DURCH P. TUORILA

I. Vergleich der Fallkurven von Suspensionen, deren Teilchen entweder über das kritische Potential elektrisch aufgeladen oder die bereits vollständig koaguliert sind, mit Suspensionen, die während der Sedimentation orthokinetisch koagulieren

Im Apparate von Wiegner-Gessner (4, 5, 17, 19) können die Fallkurven aufgenommen werden, die die Beziehung zwischen den noch schwebenden Anteilen einer Suspension (als Ordinaten) und den zugehörigen Fallzeiten (als Abszissen) angeben. Aus diesen Kurven kann man ersehen, ob das kritische elektrische Potential der Teilchen überschritten wurde, oder aber, ob die Koagulation bereits vollständig war oder schliesslich, ob die Suspension während des Sedimentierens orthokinetisch koagulierte.

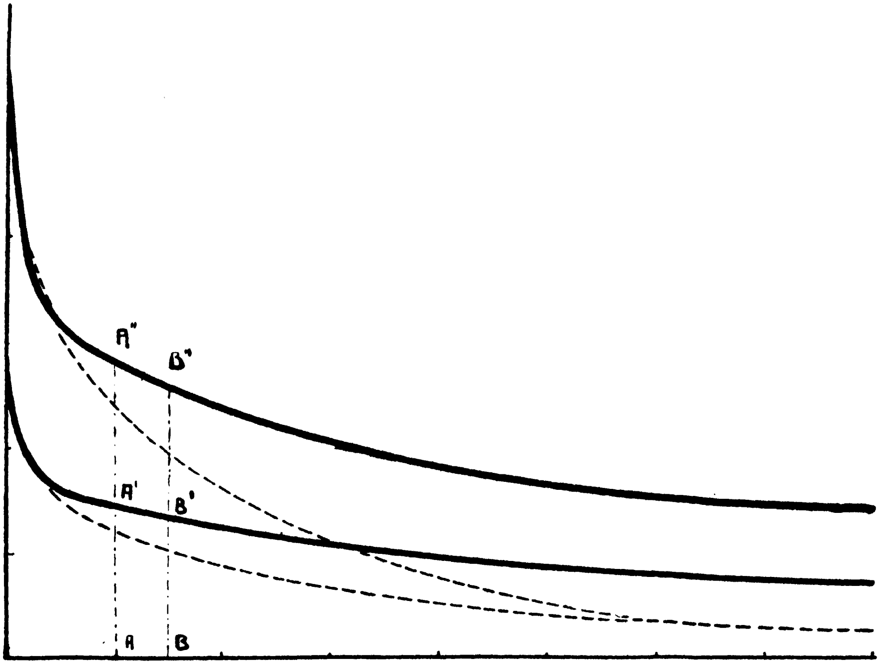
Man kann verschiedene Wege einschlagen:

(a) Man nimmt zwei Fallkurven mit *verschieden grossen Mengen* von suspendierten Teilchen im Liter Suspension, die aus der *gleichen Höhe* fallen, auf. Ist das Verhältnis der Mengen von noch schwebenden Teilchen, also das Verhältnis der Ordinaten der Fallkurven, in allen Zeitpunkten gleich dem Verhältnis der zu Beginn des Versuches suspendierten Mengen der Aufschlämmung oder sind, was dasselbe ist, die Fallkurven, deren Ordinaten die schwebenden Mengen und deren Abszissen die zugehörigen Zeiten sind, affin in bezug auf die Ordinaten, also auf die schwebenden Mengen, so koagulierte die Suspension während der Sedimentation *nicht* mehr orthokinetisch. Ihre Teilchen waren entweder über das kritische elektrische Potential aufgeladen und die Zerteilung war dadurch stabil, oder die Suspension war bereits vor der Sedimentation vollständig koaguliert. Jedenfalls fand während des Absetzens keine orthokinetische Koagulation statt.

Die Figur 1 zeigt graphisch den Zusammenhang zwischen den Zeiten (Abszissen) in Minuten und den in der Volumeneinheit der Suspension noch schwebenden Quarzteilchen (Ordinaten) in Grammen pro Liter, wenn *verschiedene Anfangsmengen* im Volumen sich aus *gleichen Fallhöhen* absetzen. Die beiden dick ausgezogenen Kurven sind in bezug auf die Mengen, also in bezug auf die Ordinaten, in gleichen Zeitpunkten affin; es ist $A\,A' : A\,A'' = B\,B' : B\,B''$.

Ihr Verlauf zeigt, dass während des Sedimentierens keine orthokinetische Koagulation stattfand. Die beiden gestrichelten Kurven dagegen geben das Absetzen von verschiedenen Mengen aus der gleichen Höhe an, wenn während des Sedimentierens orthokinetische Koagulation auftritt. Diese gestrichelten Linien liegen unterhalb der stark ausgezogenen, und

zwar weichen sie umso stärker nach unten ab, die noch schwebenden Mengen sind umso kleiner, je grösser im Anfange die fallenden Mengen sind. Die orthokinetische Koagulation vermindert die Menge der noch schwebenden Teilchen, und zwar umso stärker, je mehr Teilchen orthokinetisch wirken. Beide gestrichelten Linien für koagulierende Systeme sind *nicht affin* in bezug auf ihre Ordinaten. Hätte man von vornherein die noch schwebenden Teilchenmengen in Prozenten der anfänglichen Teilchenmengen ausgerechnet, so hätte man beim Fehlen von orthoki-



FIGUR 1.—Sedimentation von Quarz in Wasser, verschiedene Anfangsmengen aus gleicher Höhe fallend

——— orthokinetisch nicht koagulierend

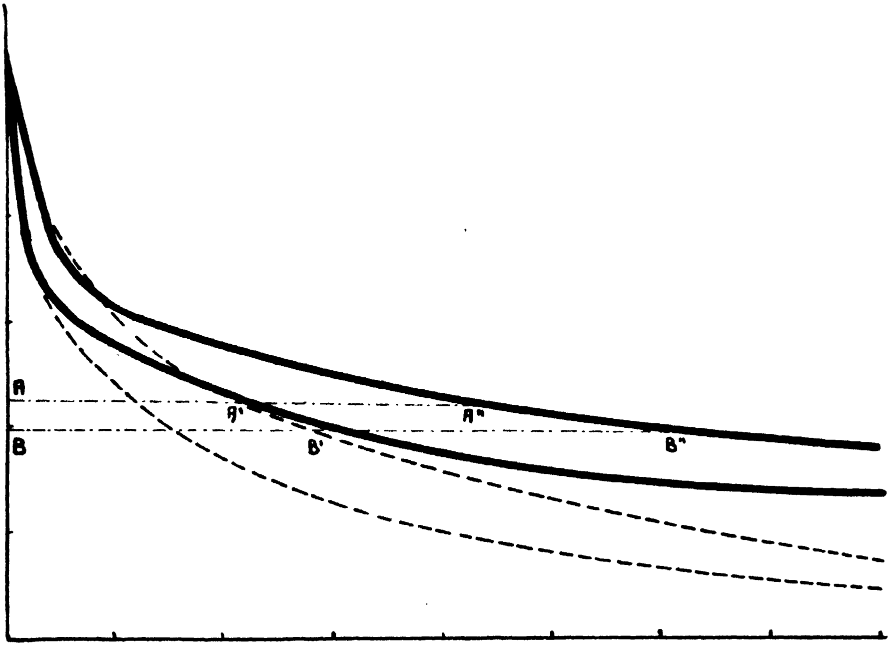
- - - - - orthokinetisch koagulierend

netischer Koagulation während des Sedimentierens aus der gleichen Höhe stets die gleichen Kurven erhalten, unbekümmert um die tatsächlich verwendeten Anfangsmengen. Eine Abweichung wäre erst bei orthokinetischer Koagulation aufgetreten.

(b) Man kann auch, um die orthokinetische Koagulation festzustellen, zwei Fallkurven von Suspensionen aufnehmen, die die *gleiche Menge* von suspendierten Teilchen im Liter enthalten, die man aber aus *verschiedenen Höhen* fallen lässt. In diesem Falle fand keine orthokinetische Koagulation während des Sedimentierens statt, wenn die Kurven, deren Ordinaten wieder die Mengen der zurückbleibenden Teilchen im Liter und deren

Abszissen die zugehörigen Zeiten sind, bei gleichen Mengen affin in bezug auf die Abszissenwerte der Zeit sind. Man erhält die Kurve der Suspension, die aus der grösseren Höhe fällt, wenn man die Zeitabszissen, die zu gleichen Mengen, also zu gleichen Ordinaten gehören, mit dem konstanten Höhenverhältnis multipliziert.

Die Figur 2 bringt die graphische Darstellung beim Absetzen von gleichen Anfangsmengen in 1 Liter Suspension aus verschiedenen Höhen. Die Zeiten in Minuten sind als *Abszissen,* die noch schwebenden im Liter



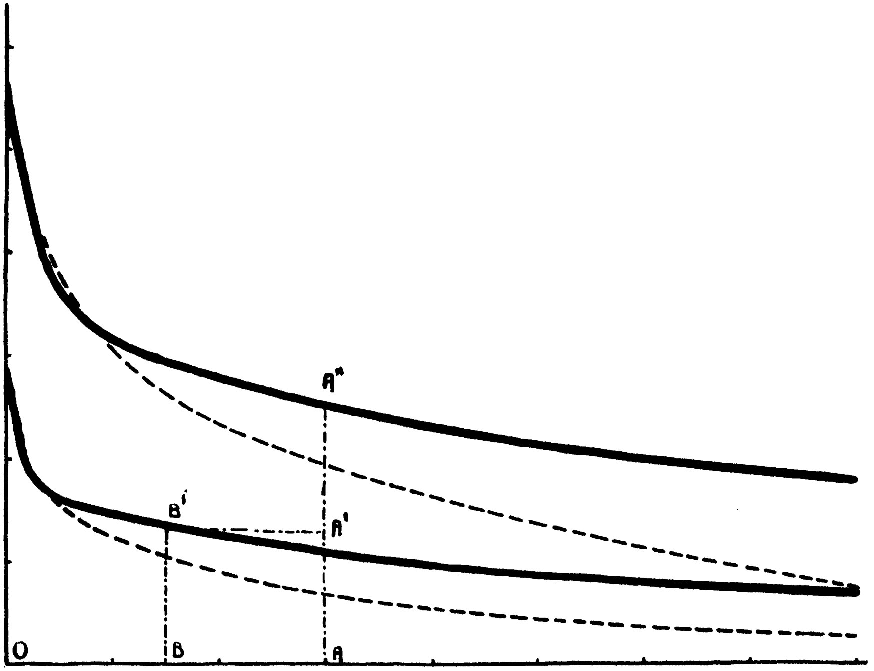
FIGUR 2.—Sedimentation von Quarz in Wasser, gleiche Anfangsmengen aus verschiedener Höhe fallend

———— orthokinetisch nicht koagulierend
------------ orthokinetisch koagulierend

Suspension zurückbleibenden Quarzmengen in Grammen als *Ordinaten* aufgetragen. Die dick ausgezogenen Kurven, die sich auf die nicht orthokinetisch koagulierende Suspension beziehen, sind affin in bezug auf die Abszissen; es ist $A\ A' : A\ A'' = B\ B' : B\ B''$.

Die gestrichelten Linien, deren Abszissen nicht affin sind, geben den Verlauf für die während der Sedimentation orthokinetisch koagulierenden Suspensionen. Die Ordinaten, d.h. die zurückbleibenden Mengen, sind kleiner als ohne Koagulationswirkung, und zwar ist die Wirkung der orthokinetischen Koagulation bei gleichen Mengen im Liter umso grösser, je grösser die Fallhöhe ist.

(c) Es könnten schliesslich auch die Fallkurven von zwei Suspensionen aufgenommen werden, die *verschiedene Mengen* im Liter der Suspension enthalten und die aus *verschiedenen Höhen* fallen. *Ohne* orthokinetische Koagulation verhalten sich in diesem Falle die in der Volumeneinheit der Suspension noch schwebenden Mengen nur dann wie die Anfangsmengen, wenn sie zu Zeiten verglichen werden, die ihrerseits im Verhältnis der Fallhöhen stehen. Die Figur 3 bringt dieses Sedimentationsverhalten



FIGUR 3.—Sedimentation von Quarz in Wasser, verschiedene Anfangsmengen aus verschiedener Höhe fallend.

———— orthokinetisch nicht koagulierend
------------ orthokinetisch koagulierend

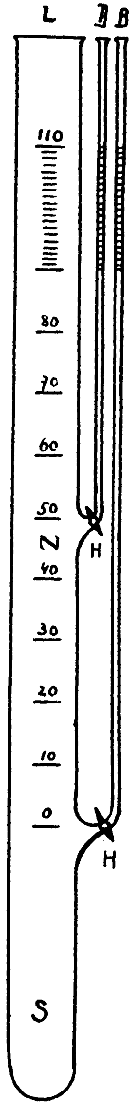
graphisch zur Darstellung. Die *Abszissen* sind die Zeiten in Minuten, die *Ordinaten* die im Liter der Suspension noch schwebenden Quarzmengen in Grammen.

Die stark ausgezogenen Linien zeigen das Verhalten der nicht orthokinetisch koagulierenden Suspensionen. Jedem Punkte B' der unteren Kurve mit der kleineren Anfangsmenge m_2 im Liter, aus der kleineren Fallhöhe H_2 fallend, entspricht ein Punkt A'' der oberen Kurve mit der grösseren Anfangsmenge m_1 im Liter aus der grösseren Höhe H_1 sedimentierend. Man erhält die Abszisse des zugeordneten Punktes A'' der oberen Kurve aus der des Punktes B' der unteren Kurve, wenn man die

Abszisse $O\ B$ des Punktes B' der unteren Kurve mit dem Mengenverhältnis $\frac{m_1}{m_2}$ und die Ordinate $B\ B'$ mit dem Verhältnis der Höhen $\frac{H_1}{H_2}$ multipliziert. Es ist also in der Figur 3: $B\ B' : A\ A'' = m_2 : m_1$ und $OB : OA = H_2 : H_1$. In der Zeichnung sind $m_2 : m_1$ und $H_2 : H_1$ wie 1 : 2 gewählt. Die gestrichelten Linien, die jeweils unterhalb der stark ausgezogenen verlaufen, zeigen die Mengen-Zeit-Abhängigkeit, also die Fallkurven für Suspensionen, die während der Sedimentation orthokinetisch koagulieren. Für die Punkte dieser Kurve gilt die eben erwähnte gegenseitige Abhängigkeit der Koordinaten der einen Kurve von denen der anderen offen sichtlich nicht.

II. Abänderung des Wiegnerschen Apparates zur Messung ein und derselben Suspension in zwei Fallhöhen (nach P. Tuorila)

P. Tuorila gab eine einfache Abänderung des Apparates von Weigner-Gessner an, die es ermöglicht, durch Ablesen der Menisken von zwei in verschiedenen Höhen angebrachten Messröhren das Absinken von Teilchen der gleichen Suspension in verschiedenen Höhen zu beobachten. Nachdem die mathematischen Gesetze der orthokinetischen Koagulation bekannt sind, ist es möglich, rein rechnerisch ohne Auswaschen der Elektrolyte und ohne Aufladung durch stabilisierende Jonen die Verteilung der Korngrössen unter Ausschaltung der orthokinetischen Koagulation zu berechnen. Sehr einfach werden die mathematischen Verhältnisse, wenn die beiden Messröhren in zwei um das Doppelte verschiedenen Höhen angesetzt werden. Man bringt also an dem bekannten Apparate an Stelle der einen Messröhre zwei an, etwa 50 cm. und 100 cm. unter dem oberen Meniskus des Sedimentationsrohres. Die folgende Figur 4 zeigt den abgeänderten Apparat.



Figur 4.—Der abgeänderte Wiegnerische Schlammapparat.

L = Fallröhre, D und B = die beiden Messröhren, H = 2 Hähne, S = Sack, in den die Teilchen nach unten sich absetzen.

Fand während der Sedimentation *keine* orthokinetische Koagulation statt, oder war die Koagulation bereits vor dem Absetzen vollständig, so liefern die direkten Ablesungen an den beiden Röhren zwei Kurven, die dem obigen Diagramm 3 für verschiedene Mengen und verschiedene Höhen entsprechen, wenn die Mengen, dargestellt durch die Ordinaten, die über

jedem Ansatzrohr noch schwebenden absoluten Teilchenmengen sind. Einfacher ist es, die Mengen auf die Volumeneinheit der Suspension (also auf 1 Liter Suspension) umzurechnen. In einer Volumeneinheit der Suspension sind nämlich über jedem Ansatzrohre zu Beginn der Sedimentation die gleichen Mengen, während die Höhen verschieden bleiben. Die Teilchenmengen im Liter der Suspension zeigen dann die durch das Diagramm 2 (gleiche Mengen im Liter, verschiedene Fallhöhen) gegebene Zeitabhängigkeit. Die dick ausgezogenen Linien sind affin in bezug auf die Zeit, also in bezug auf die Abszissen. Tritt orthokinetische Koagulation auf, so geschieht die Abnahme der Teilchenmenge im Liter aus der grösseren Höhe relativ rascher als aus der kleineren, weil das orthokinetische Mitreissen kleinerer Teilchen durch die grösseren auf längeren Fallstrecken wirksamer ist als auf kürzeren, wie die Figur 2 zeigt.

III. Umrechnung der Teilchenmenge eines orthokinetisch koagulierenden Systems auf die Teilchenmenge der nicht koagulierenden Suspension aus den in zwei verschiedenen Höhen beobachteten Teilchenmengen des koagulierenden Systems

Nach den Gesetzen der orthokinetischen Koagulation soll nun der Einfluss, den das Koagulieren auf die Veränderung der Teilchenzahl hat, berechnet werden. Das Fallen der Teilchen geschieht im Wiegnerschen Fallrohr, das in 50 cm. Tiefe (H_1) und in 100 cm. Tiefe (H_2) einen Messrohransatz hat. Es soll der Verlauf der Kurven im reinen Wasser ausgerechnet werden, wenn der Verlauf der Koagulationskurven gemessen ist.

Es sei m_2 die durchschnittliche Teilchenmenge im Liter zur Zeit t_2, die in der kleineren Fallhöhe H_2 noch schwebt, wenn die orthokinetische Koagulation t_2 Sekunden lang auf die Menge von m_0 Anfangsteilchen im Liter gewirkt hat. Ferner sei m_1 die durchschnittliche Teilchenmenge im Liter zur zweifachen Zeit $t_1 = 2t_2$, die in der doppelt so grossen Fallhöhe H_1 ($H_1 = 2H_2$) noch schwebt, wenn die orthokinetische Koagulation $2t_2$ Sekunden auf m_0 Anfangsteilchen im Liter gewirkt hat.

Nach der Formel 33 gilt, wenn man für m_H, die suspendierte Menge der Teilchen zur Zeit t_2, einmal m_2 einsetzt und M, b und t_2 belässt, und das andere Mal für m_H den Wert m_1 und für t_2 nun $t_1 = 2t_2$ benützt, während auch hier M und b dieselben bleiben:

34. $$\frac{m_2}{m_0} = \frac{1}{Mbt_2}(1 - e^{-Mbt_2})$$

(für den Fall der Teilchen aus der Höhe von 50 cm.); ferner

35. $$\frac{m_1}{m_0} = \frac{1}{Mb2t_2}(1 - e^{-Mb(2t_2)})$$

(für den Fall der Teilchen aus der Höhe von 100 cm.).

m_0 ist die Menge der Teilchen im Liter ohne orthokinetische Koagulation, $M \cdot b$ ist das Hautraumvolumen in Litern, mit dem die Menge M von fallenden Teilchen im Liter der Suspension bei der orthokinetischen Koagulation wirkt. m_1 und m_2 sind die zu den beiden Zeiten $t_1 = 2t_2$ und t_2 (Minuten) beobachteten in den verschiedenen Höhen noch schwebenden Teilchenmengen in einem Liter der Suspension. (m_1 Teilchen in der grösseren Höhe, m_2 in der kleineren Höhe).

Die Aufgabe besteht darin, aus den beobachteten Mengen m_1 und m_2, die in den Beobachtungszeiten 2 t_2 und t_2 experimentell ermittelt werden, die Menge m_0 im Liter Suspension ohne orthokinetische Koagulation zu errechnen (siehe Anmerkung):

Anmerkung:— der Gang der Rechnung ist folgender:
Die Division der Gleichung 35 durch die Gleichung 34 ergibt:

36. $$\frac{m_1}{m_2} = \frac{1}{2}\,\frac{1 - e^{-2Mbt_2}}{1 - e^{-Mbt_2}} = \frac{1}{2}(1 + e^{-Mbt_2});$$

ferner gilt anstatt der Gleichung 34 auch die reziproke Gleichung

37. $$\frac{m_0}{m_2} = \frac{Mbt_2}{1 - e^{-Mbt_2}}.$$

Aus 36 erhält man:

38. $$e^{-Mbt_2} = 2\frac{m_1}{m_2} - 1.$$

Dieser Wert wird für e^{-Mbt_2} in Gleichung 37 eingesetzt. Es ergibt sich damit

39. $$\frac{m_0}{m_2} = \frac{Mbt_2}{2 - 2\dfrac{m_1}{m_2}}$$

oder

$$2\frac{m_0}{m_2}\left(1 - \frac{m_1}{m_2}\right) = Mbt_2.$$

Wird der Wert für Mbt_2 in Gleichung 36 eingeführt, so erhält man die Formel zwischen m_1 und m_2 einerseits und m_0 und m_2 anderseits:

40. $$\frac{m_1}{m_2} = \frac{1}{2}\left(1 + e^{2\frac{m_0}{m_2}\left(\frac{m_1}{m_2} - 1\right)}\right)$$

$$\frac{2m_1}{m_2} - 1 = e^{2\frac{m_0}{m_2}\left(\frac{m_0}{m_2} - 1\right)}$$

$${}^{e}\log\left(\frac{2m_1}{m_2} - 1\right) = 2\frac{m_0}{m_2}\left(\frac{m_1}{m_2} - 1\right)$$

$$\frac{{}^{10}\log\left(\dfrac{2m_1}{m_2} - 1\right)}{2\left(\dfrac{m_1}{m_2} - 1\right)\log e} = \frac{m_0}{m_2}.$$

Nach der in der Anmerkung gegebenen Rechnung und nach Einsetzung der Zahlenwerte erhält man die gewünschte Beziehung:

$$41. \qquad \frac{m_0}{m_2} = 1{,}1513 \frac{\log\left(2\frac{m_1}{m_2} - 1\right)}{\left(\frac{m_1}{m_2} - 1\right)}$$

oder

$$42. \qquad m_0 = \frac{1{,}1513\, m_2^2 \left[\log m_2 - \log\,(2m_1 - m_2)\right]}{(m_2 - m_1)}$$

Die Gleichungen 41 oder 42 ermöglichen, m_0, die Menge Teilchen im Liter ohne orthokinetische Koagulation, zu berechnen, wenn die noch suspendierte Menge m_2 Teilchen im Liter nach t_2 Minuten am 50 cm. Rohr und die Menge m_1 Teilchen im Liter nach $t_1 = 2t_2$ Minuten am 100 cm. Rohr bestimmt sind.

Ein *Beispiel* soll den Gang der Rechnung veranschaulichen:

Beim Sedimentieren einer Quarzsuspension, im Anfange 75 g. Quarz im Liter, die mit Chlorcalcium bis zur Konzentration 0,01 normal versetzt war, seien nach $t_2 = 135$ Minuten beim Messen in der Höhe $H_2 = 50$ cm. $m_2 = 12{,}6$ g. Quarz im Liter zurückbleibend gemessen worden. In der Höhe $H_1 = 100$ cm. sind nach $t_1 = 2t_2 = 270$ Minuten nur $m_1 = 8{,}0$ g. Quarz im Liter ermittelt worden. Es muss orthokinetische Koagulation während des Sedimentierens eingetreten sein; denn ohne solche Koagulation wäre nach 135 Minuten in der Höhe 50 cm. genau dieselbe Quarzmenge im Liter gefunden worden, wie man sie in der Höhe 100 cm. nach 270 Minuten beobachtete.

Es wird verlangt, dass die Menge m_0 g. Quarzpulver im Liter berechnet werden soll, die ohne orthokinetische Koagulation in einem Liter der Suspension schweben geblieben wäre.

Es ist nach Gleichung 42, wenn $m_1 = 8{,}0$ und $m_2 = 12{,}6$ eingesetzt werden:

$$m_0 = \frac{1{,}1513 \cdot m_2^2 \left[\log m_2 - \log\,(2m_1 - m_2)\right]}{m_2 - m_1}$$

$$m_0 = \frac{1{,}1513 \cdot 12{,}6^2 \left[\log 12{,}6 - \log\,(2 \cdot 8{,}0 - 12{,}6)\right]}{12{,}6 - 8{,}0}$$

$$m_0 = \frac{1{,}1513 \cdot 12{,}6^2 \left[\log 12{,}6 - \log 3{,}4\right]}{4{,}6}$$

$$m_0 = \frac{1{,}1513 \cdot 12{,}6^2 \cdot 0{,}56889}{4{,}6} = \underline{\underline{22{,}605 \text{ g.}}}$$

Es wären also 22,6 g. in einem Liter Quarzsuspension zurückgeblieben, wenn die orthokinetische Koagulation nicht eingetreten wäre. Diese

Rechnung stimmt mit der Beobachtung sehr gut überein; denn im reinen Wasser wurden für eine Anfangsmenge von 75 g. Quarz im Liter nach 135 Minuten Fallzeit aus 50 cm. Höhe 22,9 g. Quarz im Liter statt der berechneten 22,6 g. beobachtet.

Graphisches Verfahren:

Man kann sich die Zahlenrechnung ersparen, wenn man die Werte von $\frac{m_0}{m_2}$ (berechnete Menge der suspendierten Teilchen im Liter ohne orthokinetische Koagulation, dividiert durch die in der kleineren Höhe noch schwebende beobachtete Menge bei orthokinetischer Koagulation) und von $\frac{m_1}{m_2}$ (beobachtetes Verhältnis der im Liter suspendierten Mengen bei orthokinetischer Koagulation in längerer Fallhöhe m_1 und in kürzerer Fallhöhe m_2) in ein rechtwinkliges Koordinatensystem einträgt. Um ein solches Diagramm zu entwerfen, berechnet man nach der Formel 41

$$\frac{m_0}{m_2} = 1{,}1513 \, \frac{\log\left(2\frac{m_1}{m_2} - 1\right)}{\left(\frac{m_1}{m_2} - 1\right)}$$

TABELLE 18.—Werte von $\frac{m_1}{m_2}$[a], $\frac{m_0}{m_2}$[b], *und* Mbt_2[c].

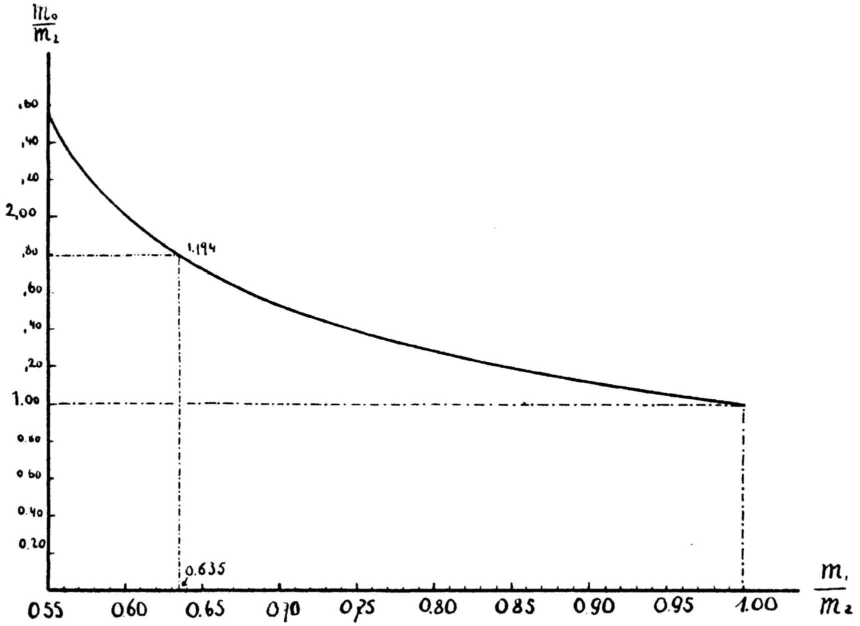
$\frac{m_1}{m_2}$	$\frac{m_0}{m_2}$	$Mbt_2 = -2{,}3026 \log\left(\frac{2m_1}{m_2} - 1\right)$
1,00	1,00	0,000
0,95	1,054	0,105
0,90	1,116	0,223
0,85	1,189	0,357
0,80	1,277	0,511
0,75	1,386	0,693
0,70	1,527	0,916
0,65	1,720	1,204
0,60	2,012	1,609
0,55	2,559	2,303

[a] $\frac{m_1}{m_2}$ ist $\frac{\text{beobachtete Teilchenmenge in Gramm pro Liter in der doppelten Höhe}}{\text{beobachtete Teilchenmenge in Gramm pro Liter in der einfachen Höhe}}$

[b] $\frac{m_0}{m_2}$ ist $\frac{\text{berechnete Teilchenmenge in Gramm pro Liter ohne orthokinet. Koagulation}}{\text{berechnete Teilchenmenge in Gramm pro Liter bei orthokinet. Koagulation im kurzen Rohr}}$

[c] Mbt_2 ist Hautraum in Literzeiten.

für eine Reihe von $\frac{m_1}{m_2}$ - Werte die zugehörigen $\frac{m_0}{m_2}$ - Werte. Das ist in der nächsten Tabelle geschehen. Zugleich sind noch die zugehörigen Werte für die Hauträume (Hautraum volumen mal Zeit $= Mbt_2$) eingetragen, die vielleicht für spezielle Berechnungen einen Wert haben können. Zur



FIGUR 5.—Diagramm zur graphischen Ermittlung der $\frac{m_0}{m_2}$-Werte aus den beobachteten $\frac{m_1}{m_2}$-Werten.

Berechnung von m_0 aus $\frac{m_1}{m_2}$ braucht man die Zahlen für das Hautraumvolumen nicht.

Die Werte von $\frac{m_1}{m_2}$ sind nun in der nächsten Figur 5 als Abszissen, die zugehörigen Werte von $\frac{m_0}{m_2}$ als Ordinaten eingetragen.

In der Figur 5 bedeutet die Abszisse $\frac{m_1}{m_2}$ das Verhältnis der auf das gleiche Volumen der Suspension bezogenen, in den um das Doppelte verschiedenen Höhen abgelesenen Mengen der suspendierten Teilchen, wobei m_1 die Menge in der grösseren, m_2 die in der kleineren Höhe ist. Die

Ordinate $\frac{m_0}{m_2}$ ist die ohne orthokinetische Koagulation berechnete Menge von Teilchen im Liter Suspension, dividiert durch die in der kleineren Höhe beobachtete. Die Multiplikation der für einen beobachteten Abszissenwert $\left(\frac{m_1}{m_2}\right)$ abgelesenen Ordinate $\left(\frac{m_0}{m_2}\right)$ mit m_1, der Menge von Teilchen in der kleineren Höhe, gibt direkt den gewünschten Wert m_0, d.h. die Menge der Teilchen, in der Volumeneinheit zurückbleibend, wenn die orthokinetische Koagulation nicht gewirkt hätte.

Im obigen Beispielsfalle ist $\frac{m_1}{m_2} = \frac{8{,}0}{12{,}6} = 0{,}635$. Man liest die zur Abszisse 0,635 zugehörige Ordinate $\frac{m_0}{m_2} = 1{,}794$ ab. Die Multiplikation mit $m_2 = 12{,}6$ ergibt den Wert $m_0 = 22{,}6$ ohne orthokinetische Koagulation.

Natürlich sind die Berechnungen von P. Tuorila auch im Falle der Schlämmanalyse nur insoweit exakt, als die Vorbedingungen für die Giltigkeit seiner Gleichungen erfüllt sind, wie sie auf der Seite 225 umschrieben sind. Man bekommt die Werte im allgemeinen in guter Annäherung richtig.

IV. Experimentelle Bestägigung der vorhergehenden Rechnung durch Vergleich der berechneten Werte mit den beim Fallen im reinen Wasser direkt beobachteten Zahlen

Es sei noch ein Beispiel einer Schlämmanalyse angeführt, die mit einer während der Sedimentation orthokinetisch koagulierenden Quarzsuspension im abgeänderten Wiegnerschen Schlämmapparat mit zwei Messröhren angestellt wurde. Es wurde einmal mit $CaCl_2$ koaguliert, bis die Konzentration des Gemisches 0,025 N war. Die Salzlösung wurde mit einem

TABELLE 19.—Sedimentation einer orthokinetisch koagulierenden Quarzsuspension
Koagulator $CaCl_2$. Konzentration im Koagulationsgemisch: 0,025 N

t_2 Zeit in Minuten	m_2 g. Quarz pro Lit. b. Messung in Höhe H_2= 50 cm.	$t_1 = 2t_2$ Zeit in Minuten	m_1 g. Quarz pro Lit. b. Messung in Höhe H_1= 100 cm.	m_0 g. Quarz pro Lit. ohne Koagulation: ber.	m_0 g. Quarz pro Lit. ohne Koagulation: beob. im reinen Wasser	$\frac{m_1}{m_2}$	Hautraum Mbt_2 Liter-sekunden
0	75,0	0	75,0	75,0	75,0	1,000	0,00
5	58,4	10	55,0	62,1		0,942	0,13
30	33,9	60	31,7	36,3	37,2	0,935	0,14
60	24,3	120	18,8	32,4	32,0	0,774	0,60
90	16,6	180	12,3	23,4	26,9	0,741	0,73
120	9,7	240	6,66	15,3	26,8	0,687	0,99

langen Glasrohr zu Beginn des Versuches möglichst rasch und gleichmässig zugesetzt. In einem anderen Versuch wurden die Quarzteilchen im reinen Wasser (Fallhöhe 50 cm.) fallen gelassen. Dabei fand keine orthokinetische Koagulation statt.

Die Werte der 5. Spalte m_0, *berechnet* ohne Koagulation, und der 6. Spalte m_0, *beobachtet* im reinen Wasser, stimmen bis auf den letzten gut überein, ein Beweis, dass es gelingt, die Zerteilung einer elektrolytfreien Suspension aus den Koagulationskurven, die in zwei verschiedenen Höhen beobachtet wurden, innerhalb der Fehler sehr angenähert auszurechnen. Es sei nochmals darauf hingewiesen, dass zur exakten Giltigkeit der Formeln, die auf Seite 225 angegebenen Vorbedingungen erfüllt sein müssen.

V. Die Sedimentation vollständig koagulierter Systeme

Sind die Suspensionen von vornherein vollständig koaguliert, so kann keine orthokinetische Koagulation während der Sedimentation mehr stattfinden, wie folgende Tabelle 20 zeigt, die sich auf die Sedimentation einer Quarzsuspension bezieht die vor dem Versuche mit 1-normaler $CaCl_2$-Lösung vollständig koaguliert wurde.

TABELLE 20.—Sedimentation einer völlig koagulierten Quarzsuspension, bestimmt in den Fallhöhen 50 und 100 cm.

Koagulator: $CaCl_2$. Konzentration im Koagulationsgemisch: 1 N

t_2 Zeit in Minuten	m_2 g. Quarz pro Liter bei Messung in Höhe H_2= 50 cm.	$2t_2$ Zeit in Minuten	m_1 g. Quarz pro Liter bei Messung in Höhe H_1= 100 cm.
0	75,0	0	75,0
5	53,3	10	55,0
15	38,6	30	39,0
30	28,4	60	28,5
60	16,1	120	15,8
90	6,0	180	6,3
120	0,4	240	0,3

Die Kurven sind affin in bezug auf die Zeit. Orthokinetische Koagulation fand also nach der vollständigen Koagulation nicht mehr statt.

E. ZUSAMMENFASSUNG DER ERGEBNISSE

Es wird zusammenfassend über die Arbeiten berichtet, die im Agrikulturchemischen Laboratorium der Eidgen. Technischen Hochschule in Zürich in den letzten Jahren über Koagulationen von *monodispersen* Systemen mit gleichgrossen Teilchen und von *polydispersen* Systemen mit verschiedengrossen Teilchen ausgeführt worden sind. Man hat nach

R. Zsigmondy und M. v. Smoluchowski zwischen *rascher* und *langsamer* Koagulation zu unterscheiden, falls eine elektrische Entladung der Teilchen für das Eintreten der Koagulation verantwortlich zu machen ist. Die Koagulation ist rasch, wenn die Entladung der Teilchen vollständig war; sie ist langsam, wenn die Teilchen nur unvollständig unter ein bestimmtes kritisches elektrisches Potential entladen wurden. Tritt nach vollständiger oder nur teilweiser elektrischer Entladung das Zusammenstossen der Teilchen infolge ihrer Brownschen Bewegung mit einer in allen Richtungen des Raumes gleichgrossen Wahrscheinlichkeit ein, so ist die Koagulation nach der Bezeichnung des Verfassers eine rasche oder langsame *perikinetische* Koagulation. Ist aber die Wahrscheinlichkeit des Zusammenstosses der Teilchen in einer Richtung grosser als in den andern Richtungen, wie es z.B. bei der einseitigen Bewegung grösserer Teilchen neben kleineren infolge der Wirkung einer äusseren Kraft wie Schwerkraft oder Zentrifugalkraft der Fall ist, so wurde die dadurch bewirkte Koagulation rasche oder langsame *orthokinetische* Koagulation vom Verfasser neu benannt. Die rasche oder langsame perikinetische Koagulation kann in mono- oder polydispersen Systemen erfolgen; dagegen ist für das Zustandekommen der orthokinetischen Koagulation stets Voraussetzung, dass die Teilchen von vornherein polydispers sind.

In der Bodenkunde haben wir es nur ganz ausnahmsweise mit monodispersen Systemen zu tun. Meist sind bodenkundliche Systeme polydispers und viele Koagulationen, die man bisher beobachtete, haben nichts mit den perikinetischen Koagulationen der Kolloidchemie zu tun, sie sind orthokinetisch, worauf in Zukunft zu achten sein wird. Unbedingt notwendig waren für die Bodenkunde quantitative Untersuchungen der Koagulation polydisperser Systeme, seien sie perikinetisch oder orthokinetisch. Man sollte stets scharf unterscheiden:

(a) Rasche perikinetische Koagulation von monodispersen Systemen.
(b) Langsame perikinetische Koagulation von monodispersen Systemen.
(c) Rasche perikinetische Koagulation von polydispersen Systemen.
(d) Langsame perikinetische Koagulation von polydispersen Systemen.
(e) Rasche orthokinetische Koagulation von polydispersen Systemen.
(f) Langsame orthokinetische Koagulation von polydispersen Systemen.

Voraussetzung für die mathematische Ableitung der Gesetze ist, dass die Teilchen kugelförmig sind und dass eine Verminderung des elektrischen Potentials die Ursache der Koagulation ist. Es gibt noch eine Reihe von anderen Koagulationsursachen. Die Koagulation stäbchenförmiger Teilchen und die Koagulation elektrisch entgegengesetzt geladener Teilchen werden gegenwärtig in unserem Institute bearbeitet. Untersuchungen über die unter a, b, c, und e angeführten Koagulationsformen sind abgeschlossen worden, die Ergebnisse sind folgende:

(1) Es wird bewiesen, dass die Gesetze von M. v. Smoluchowski für die *rasche perikinetische* Koagulation *monodisperser* Systeme in einem weiten Bereiche vom amikroskopischen bis nahezu zum mikroskopischen Gebiete für Goldsole gültig sind. Amikroskopische Sole waren bisher noch nicht geprüft worden (Tabellen 1 und 2). Auch monodisperse Kaolinzerteilungen koagulieren nach diesen Gesetzen (Tabelle 3). P. Tuorila arbeitete ein besonderes neues Zählverfahren ohne Schutzkolloidzusatz aus.

(2) Es wird durch ultramikroskopische Zählungen die *langsame perikinetische* Koagulation *monodisperser* Systeme untersucht. Nach M. v. Smoluchowski lässt sich die Zahl der wirksamen Zusammenstösse der Ultramikronen bei unvollständiger Entladung berechnen. Sie steht in bestimmten Fällen in Zusammenhang mit dem Hydratationsverhalten der Jonen, wie es auch beim Basenaustausch an Kolloiden heraustritt (Tabellen 4 und 5).

(3) Die *rasche perikinetische* Koagulation *polydisperser* Systeme wird auf Veranlassung des Verfassers von H. Müller berechnet (Endformel 13). Die Müllerschen Formeln werden durch besondere Versuche an Goldsolen bestätigt (G. Wiegner und P. Tuorila) (Tabellen 6 und 7). Sie sind übrigens auch für Tonzerteilungen brauchbar. Polydisperse Systeme koagulieren stets rascher wie monodisperse mit der gleichen Anfangsteilchenzahl. Der Unterschied zwischen mono- und polydispersen Systemen von gleicher Teilchenzahl macht sich im polydispersen Systeme erst bei Radienverschiedenheiten 1 : 10 deutlich geltend. Die Teilchenmassen sind dann im gleichen Systeme 1000 mal verschieden. Der Einfluss der Teilchenverschiedenheit auf den perikinetischen Koagulationsverlauf polydisperser Systeme ist also gering, was geologisch und bodenkundlich von Bedeutung ist.

(4) Die Gesetze der *raschen* und *langsamen orthokinetischen* Koagulation wurden von P. Tuorila im weiteren Verlaufe dieser Arbeiten in unserem Institute entwickelt. Es wurden Formeln abgeleitet, die unter bestimmten, genau präzisierten Voraussetzungen für den Fall gelten, dass nach der elektrischen Entladung der Teilchen irgendeine Gruppe von grösseren Teilchen durch eine andere Gruppe von kleineren Teilchen hindurchfällt. Die Formeln sind als Endformeln 32 und 33 gegeben. Der Effekt der orthokinetischen Koagulation ist für die Beurteilung einer Sedimentation in Suspensionen oder bei Schlämmanalysen oft viel wichtiger als der der perikinetischen.

(5) Es wird von P. Tuorila angegeben, wie der Schlämmapparat von G. Wiegner so abgeändert werden kann, dass man aus der Beobachtung der Fallkurven von orthokinetisch koagulierenden Systemen in zwei verschiedenen Höhen die ursprüngliche Dispersität herausrechnen kann. Ein Beispiel dafür wird gegeben.

Am Schlusse dieser zusammenfassenden Arbeit dankt der Verfasser herzlich seinen Mitarbeitern, insbesondere Herrn Dr. P. Tuorila, ferner

Herrn Dr. H. Müller dafür, dass sie das bodenkundlich wichtige Gebiet der Koagulation, das zum wissenschaftlichen Programm des hiesigen Instituts gehörte, mit Erfolg bearbeiteten. Wenn heute über das Gebiet der *perikinetischen* Koagulation *monodisperser* Systeme hinaus die Beherrschung der Gesetze der *perikinetischen* Koagulation *polydisperser* Systeme und schliesslich auch der *orthokinetischen* Koagulation *polydisperser* Systeme gelungen ist, so verdankt man das ihren Arbeiten. Diese sind auch für bodenkundliche Probleme (Sedimentation und Schlämmanalyse) von grosser Bedeutung.

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PAPERS NOT SUBMITTED

The following papers were not received for publication but were presented before Commission I; page references following each title refer to the Abstracts of the Proceedings of the First International Congress of Soil Science, June 13–22, 1927.

DIE MECHANISCHE ZUSAMMENSETZUNG DER DÜNENSANDE (NACH ATTERBERG) UND IHRE AUSSCHLAGGEBENDE BEDEUTUNG FÜR DEREN WUCHSLEISTUNGEN ALS WALDBÖDEN

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Prague, Czechoslovakia